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Agricultural Planning with Production Rigidities: Theory and Practice

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3.1. Abstract

This research has introduced a new approach to agricultural production analysis and planning and used the Arava region as a laboratory for empirical development and implementation.

A study of the institutional setting, historical development, and production pattern in the Arava was conducted; and a data base for empirical research was established. Concurrently, a micromodel for producer behavior under uncertainty with production rigidities was developed. It establishes optimal decision rules for adoption of new technologies, land use patterns, and input selections. The micromodel was extended to evaluate the impacts of sectorial monetary and fiscal policies on farmers' behavior. By explicitly considering the distribution of certain characteristics among farms, aggregation from the microlevel to the macrolevel gave analyses of efficiency and equity impacts of alternative policies. Furthermore, in a dynamic model of the regional development process, optimal public research policy and farmer production decisions over time were investigated.

The data base was used to empirically estimate water and other input allocations among crops by individual farmers given data on total use of each input. Moreover, the production functions for five of the main crops were estimated using efficient estimation techniques for multicrop production. Results suggest that human capital explains important differences in productivity among farms and that technology has improved rapidly for the most important crops.

4.1. Introduction

The objective of the research project was to introduce a new approach to agricultural planning and to use the Arava region as a laboratory for empirical development and implementation. The new methodology incorporates some of the key features of agricultural production:¹ production rigidities, yield and price uncertainties, and rapid technological change.

The research was conducted in two stages. Each stage included two research efforts: an empirical one and a theoretical one.

The empirical part of the first stage focused on familiarization with the Arava, its people and its problems. Numerous meetings with policymakers, farm advisers, and farmers were held; and several data sources were examined. This effort resulted in a data base for empirical research as well as two descriptive manuscripts in English and Hebrew.

The conceptual part of the first stage concentrated on developing micro models for producers' behavior under uncertainty and production rigidities and, in particular, adoption of new technologies, land-use patterns, and crop and input selection.

The empirical component of the second stage consisted of estimation of the allocation of water and other inputs among crops by individual farmers given data on total use of each input. Moreover, the production functions for five of the main crops were estimated using efficient estimation techniques for multicrop production. The theoretical component of the second stage generalized the conceptual micro model and introduced explicitly agricultural policies such as price supports, credit subsidies, and land diversion policies. Using Johansen's aggregation procedures, aggregate measures of welfare were

obtained, and the aggregate impact of government policies were investigated qualitatively.

A dynamic model of the regional development process was also developed; it investigates optimal government allocation to research and development over time and the dynamic paths of land use, capital/labor ratio of new technologies, and the change of rental rates over time.

Following are summaries of the findings of the various components of the research during the two stages.

4.2. Past and Present in the Agricultural Development of the Arava

The Arava is part of the Afro-Syrian fault line and includes the plains between the Red Sea and the Dead Sea. The uniqueness of the Arava region stems from two factors:

1. The border between Israel and Jordan passes through the lowest location of the fault. It is a frontier area with all the defense implications as well as protecting the highway to Eilat. Thus, spreading settlements and population in the Arava region are of national priority.
2. The area is arid but with high minimum and maximum temperatures; this endows the region with ecological advantages. The first factor explains the need for creating settlements in the Arava. The second factor, i.e., the special ecological features of the region, contributes to the development and planning of the region in a unique way.

In the papers, "Economic Development of Sparsely Populated Areas," and "The Development Process of an Arid Zone: The Case of the Arava Region in Israel," the Arava is used as a case study. Its development in population and number of settlements is depicted in Table 1, and some of the main observations of these papers follow.

TABLE 1
Population and Settlements in the Arava

	1964	1965	1970	1973	1975	1977	1980	1982
Number of settle- ments	1	2	4	5	8	11	13	16
Popula- tion	80	270	660	893	1,500	2,000	2,200	2,900

The development of agriculture in the Arava followed several stages:

1. Search for the appropriate technology (1952-1967). Several experimental settlements were established in an attempt to adopt existing agricultural technologies and invent new technologies appropriate to the Arava conditions. Around 1969, viable agricultural practices were available in the production of winter vegetables and dates. One essential component of the new technologies was drip irrigation.
2. Solidification of permanent settlements (1968-1973). The main settlements, especially Moshav Ein Yahav and Kibbutz Yotveta, have grown and prospered economically. They refined agricultural practices, especially drip irrigation, and identified the most appropriate crop for the region.
3. Rapid Growth (1974-1979). The number of settlements grew from 5 to 13, and its population from 900 to 2,000. Most of the growth represents expansion of use of land and water resources with the already available technologies.
4. Saturation (1980-present). The agricultural establishment in the Arava has met its limits mostly because of inelastic demand and heavy competition with the north on appropriation of resources. Some of the key features characterizing the development process in the Arava are: (a) binding physical constraints serve as inducement for new innovations, (b) close cooperation between public research institutes and the farmers have resulted in practical research products and fast diffusion of innovations, (c) the emphasis on quality of settlers (in terms of education and background) allowed active interaction with researchers and resourcefulness in interaction with hostile and unfamiliar environments, and (d) ideological consideration and constraints have had paramount importance in shaping the development process.

While the development process might not have occurred without the ideological impetus, ideological rigidity might restrict its growth and reduce efficiency in resource use.

A multitude of data sources was generated throughout the development process in the Arava. The challenge we confronted was to merge these data sources and generate a consistent and reliable data base for econometric analysis. The outcome is described in Hochman, Just, and Zilberman, "The Dynamics of Agricultural Settlement of Sparsely Populated Environment: The Case of the Arava Region in Israel," in Resources and Development in Sparsely Populated Arid Environment (to be published by Westview Press) and in Hochman, Vitkan, and Zilberman, "The Settlement of the Arava Region in Israel," Ben-Gurion University of the Negev, Beer-Sheva, Israel, March, 1983.

4.3. A Micro Model of Farmer Behavior Under Uncertainty and Production Rigidities

A first version of the micro model appeared in "Stochastic Structure, Farm Size, and Technological Adoption." The results presented here are then from "Equity and Efficiency in Agricultural Production Systems."

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 $\pi_0 = p_0 y_0$ with mean $E(\pi_0) = m_0$ and variance $V(\pi_0) = \sigma_0$ where p_0 and y_0 are the price and yields, respectively, under the traditional technology. Suppose a new technology is introduced under which the farmer can allocate some of his land to the traditional crop (at traditional costs) and some of his land to a new crop (or a new method of producing the same crop).

The second crop (technique), which will be referred to as the "new crop," may be a high-yielding variety or a cash crop utilizing a new input such as fertilizers, insecticides, and improved seeds. On the other hand, it may be more vulnerable to weather variations so that there is a relatively greater degree of uncertainty regarding the returns per acre. Additional (and subjective) uncertainty may also accompany the new crop due to the fact that 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 the traditional crop.

Suppose production of the new crop requires a cost of w for the new input per acre to attain a subjective distribution of net returns per acre π_1 with mean $E(\pi_1) = m_1$ and variance $V(\pi_1) = \sigma_1^2$. 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, and $p_1 y_1$ is normally distributed. Also, suppose that net returns of the traditional and new crops are correlated with $\text{corr}(\pi_0, \pi_1) = \rho$.

Specifically, assume

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

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

The farmer must either allocate all his land to the traditional technology or incur a fixed set-up cost, k , for the new technology in which case he can allocate his land in any proportion between the two technologies. Thus, the investment decision is a discrete choice whereas the land-allocation decision is a continuous choice. In addition to the fixed set-up cost, k , for which the annualized cost is rk , the farmer also incurs a variable cost, w per 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

$$(4.3.1) \quad \begin{array}{l} \max_{\substack{I = 0, 1 \\ L_0, L_1}} EU[p_L L + \pi_0 L_0 + I(\pi_1 L_1 - rk)] \end{array}$$

subject to

$$L_0 + IL_1 \leq L$$

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

$$L_0, L_1 \geq 0.$$

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

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

$$(4.3.2) \quad U_0(L) = EU[(p_L + \pi_0) L].$$

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

$$(4.3.3) \quad \max_{L_0, L_1} EU[p_L L + \pi_0 L_0 + \pi_1 L_1 - rk]$$

subject to

$$L_0 + L_1 \leq L$$

$$k + wL_1 \leq K$$

$$L_0, L_1 \geq 0.$$

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

$$(4.3.4) \quad L_1 = \bar{L}_1 \equiv \begin{cases} 0 & \text{if } L_1^* < 0 \text{ or } k > K \\ L_1^* & \text{if } 0 \leq L_1^* \leq L \text{ and } (K - k)/w > 0 \\ (K - k)/w & \text{if } L > L_1^* > (K - k)/w > 0 \\ L & \text{if } (K - k)/w > L \text{ and } L_1^* > L \end{cases}$$

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

where

$$(4.3.5) \quad L_1^* = \frac{E(\Delta\pi)}{\phi V(\Delta\pi)} + L R$$

$$(4.3.6) \quad R = \frac{\sigma_0^2 - \rho\sigma_0\sigma_1}{\sigma_0^2 + \sigma_1^2 - 2\rho\sigma_0\sigma_1}$$

$$(4.3.7) \quad \Delta\pi = \pi_1 - \pi_0$$

$$(4.3.8) \quad \phi = \frac{-U''(W)}{U'(W)}$$

$$(4.3.9) \quad W = p_L L + \pi_0 L + E(\Delta\pi) L_1 - rk.$$

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

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

To determine the technology choice, let

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

Figure 1

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

4.3.1. Behavior of Individual Farmers Under Alternative Policies

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

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

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

Crop insurance is assumed to be actuarially fair and lower the variability of returns per 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). The effect of price stabilization is thus the same as for crop insurance.

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

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

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

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

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

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

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

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

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

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

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

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

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

connected with adoption is to increase the intensity of adoption among adopting farmers who have not already fully adopted. Also, the tendency to adopt increases among all nonadopting farmers except for those who have insufficient credit to finance the initial unavoidable pecuniary costs.

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

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

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

4.4. Regional Models

The conceptual study of the economic behavior at the regional level followed two directions: (1) a static analysis of the impacts of agricultural policy on a region with heterogeneous, risk-averse farm units and (2) a dynamic model of regional development with production rigidities and public research and development.

4.4.1. Static Analysis

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

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

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

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

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

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

Figure 2

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. To simplify, the availability of credit is also assumed to be related to initial wealth or, equivalently, farm size, following the equation

$$K = aL.$$

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

$$(4.4.1) \quad U_0(L) = (p_L + m_0) L - \frac{\phi}{2} \sigma_0^2 L^2$$

$$(4.4.2) \quad U_1(L, L_1) = (p_L + m_0) L + (m_1 - m_0) L_1 - rk - \frac{\phi}{2} [\sigma_0^2 (L - L_1)^2 + \sigma_1^2 L_1^2 + 2\rho \sigma_0 \sigma_1 L_1 (L - L_1)].$$

Using the model of section 4.3, the relationship of adoption intensity and farm size can be determined as illustrated in Figures 3 and 4. First, the intensity of adoption as measured by L_1 is physically constrained to lie between the lines $L_1 = L$ and $L_1 = 0$. Second, the intensity of adoption is constrained to lie on or below the credit limitation boundary $L_1 = (K - k)/w = (aL - k)/w$. Subject to these limitations, the intensity of adoption given adoption follows L_1^* in (5). Finally, there is a minimum farm size, L_1 , where fixed costs can be adequately spread to make adoption worthwhile.

Figure 3

Figure 4

Note that Figure 3 is drawn to depict the case where the major barriers to adoption are risk aversion and set-up costs. Below farm size $\hat{L}_{11}$, fixed costs cannot be adequately spread to justify adoption. At farm size $\hat{L}_{12}$, perceived risk becomes sufficiently large to induce diversification. In this case, credit never becomes binding since the credit line $L_1 = (aL - k)/w$ is above the adoption expansion path beyond $\hat{L}_{11}$.

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

Of course, many other possibilities in addition to the cases in Figures 3 and 4 exist. For example, Figure 4 is drawn to depict the case of risk neutrality where $L_1 = L_1^*$ becomes vertical at $L = 0$. If risk aversion is introduced in Figure 4, then $L_1 = L_1^*$ rotates downward and intersects $L_1 = L$ as in Figure 3. Thus, another critical point beyond $\hat{L}_{12}$ may occur where farmers switch back to diversification. Also, with higher fixed cost k , the credit line moves downward in a vertically parallel fashion and may eliminate the full adoption segment. Or if credit per 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 old) but farms beyond some critical size (not shown) will not adopt if $R < 0$ (the high correlation case) since L_1^* will have negative slope and eventually intersect $L_1 = 0$. In

addition, with lower expected gains, $E(\Delta\pi)$, or higher risk aversion, ϕ , the L_1^* line moves down in parallel fashion and may eliminate the full adoption segment and possibly also the binding credit segment. Finally, several factors such as relative profitability, relative riskiness, risk aversion, credit, and fixed costs can cause the critical point $\hat{L}_1$ at which adoption occurs to move to the right, possibly eliminating the binding credit segment or both the binding credit and full adoption segments.

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

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

$$(4.4.3) \quad E(\bar{U}_i) = \int_{\hat{L}_{i0}}^{\hat{L}_{i3}} \bar{U}_i(L) f(L) dL$$

where

$$(4.4.4) \quad \bar{U}_1(L) = \begin{cases} U_0(L) & \text{if } \hat{L}_{10} \leq L < \hat{L}_{11} \\ U_1(L, L) & \text{if } \hat{L}_{11} \leq L \leq \hat{L}_{12} \\ U_1(L, L_1^*) & \text{if } \hat{L}_{12} \leq L < \hat{L}_{13} \end{cases}$$

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

$$(4.4.5) \quad \bar{U}_2(L) = \begin{cases} U_0(L) & \text{if } \hat{L}_{20} \leq L \leq \hat{L}_{21} \\ U_1\left(L, \frac{aL - k}{w}\right) & \text{if } \hat{L}_{21} \leq L \leq \hat{L}_{22} \\ U_1(L, L) & \text{if } \hat{L}_{22} \leq L \leq \hat{L}_{23} \end{cases}$$

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

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

$$(4.4.6) \quad E(Y_i) = \int_{\hat{L}_{i0}}^{\hat{L}_{i3}} Y_i(L) f(L) dL,$$

where

$$(4.4.7) \quad Y_1(L) = \begin{cases} m_0 L & \text{if } \hat{L}_{10} \leq L \leq \hat{L}_{11} \\ m_1 L - rk & \text{if } \hat{L}_{11} \leq L \leq \hat{L}_{12} \\ m_0 L + (m_1 - m_0) L_1^* - rk & \text{if } \hat{L}_{12} \leq L \leq \hat{L}_{13} \end{cases}$$

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

$$(4.4.8) \quad Y_2(L) = \begin{cases} m_0 L & \text{if } \hat{L}_{20} \leq L \leq \hat{L}_{21} \\ m_0 L + E(\Delta\pi) \frac{aL - k}{w} - rk & \text{if } \hat{L}_{21} \leq L \leq \hat{L}_{22} \\ m_0 L + E(\Delta\pi) L_1^* - rk & \text{if } \hat{L}_{22} \leq L \leq \hat{L}_{23} \end{cases}$$

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

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

The propositions in this section are proven by solving for L_{i1} and L_{i2} , performing the integration in (12) and (15), and evaluating the qualitative effects of various policies on the resulting policy performance measures. Note that all results assume no product price effects of

adoption. Such effects can be easily introduced but the exposition and understanding of propositions becomes less clear when such effects are introduced. Furthermore, the modifications introduced by such considerations follow intuition.

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

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

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

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

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

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

Proposition 12: Crop Insurance or Price Stabilization. (a) If the new technology pertains to a new crop, then the effect of actuarially fair crop insurance or mean-preserving price stabilization is to improve aggregate farm income if the major barriers to adoption are risk aversion and set-up costs, while farmer welfare is unaffected if the major barriers to adoption are credit and set-up costs. All farmers, whether adopting or not, benefit in the former case. Also in the former case, the minimum scale required for adoption declines, while the maximum size of fully adopting farms increases so that overall adoption increases. (b) If the new technology pertains to the existing crop, then the effect of actuarially fair crop insurance for mean-preserving price stabilization is to improve aggregate farm income according to the expected utility criterion if the major barriers to adoption are risk aversion and set-up costs, while farmer well-being is unaffected in the case where the major barriers to adoption are credit and set-up costs. However, according to the expected income criterion, the average well-being of farmers improves only in the case with high correlation ($\rho > \beta_0$), while the average well-being of farmers declines in the low correlation case ($\rho < \beta_0$). In the case where the major barriers to adoption are risk aversion and set-up costs, the well-being of each individual farmer improves according to the expected utility criterion; but only the large partial-adopting farmers are affected according to the expected income criterion. The welfare of these

farmers is improved in the case of high correlation and adversely affected in the case of low correlation. Also, in the case where the major barriers to adoption are risk aversion and set-up costs, the minimum scale required for adoption is decreased, while the maximum size of fully adopting farms is increased so overall adoption increases.

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

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

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

Proposition 14: Fixed Cost Subsidy. The effect of a subsidy on the fixed cost of adoption (a one-time subsidy for adoption) is to increase the aggregate welfare of farmers. Small nonadopting farms are unaffected, while

the welfare of larger fully and partially adopting farmers increases. The minimum scale required for adoption declines. The maximum size of fully adopting farms is unaffected in the case where the major barriers to adoption are risk aversion and set-up costs, while the minimum scale associated with full adoption declines in the case where credit and set-up costs are the major barriers to adoption. Overall adoption increases in either case.

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

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

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

The above propositions, in context of the six classes of farmers identified by (13) and (14), reveal the varying qualitative effects that can be achieved by different policies. They demonstrate the importance of different types of barriers to adoption and, perhaps more importantly, the need to

operate with more than a single policy regime. In other words, positive equity effects can be achieved more readily by operating with a mix of policies rather than a single policy.

The aggregate model in this section is based on the micro model of section 4.3. The aggregate relationship is used to analyze the efficiency and equity impacts of alternative policies.

4.4.2. Dynamic Analysis

A model incorporating some of the main features characterizing the development process in the Arava is presented in Zilberman, Hochman, and Höchman, "A Dynamic Model of Regional Development of Production Rigidities of Public Research and Development," Working Paper, Ben-Gurion University of the Negev, Beer-Sheva, Israel. The model analyzes the optimal settlement policy for a region with a given amount of land. The production technologies have putty clay properties, and the technological change is the result of government research and development. The region faces an inelastic supply of funds for public and private investments, given output and labor prices.

The objective of the optimal settlement plan is to maximize the discounted value of the economic surplus generated by the region. At each period, the decision variables are: government spending on research and development, the amount of land allocated to the new technology, and the per acre capital and labor ratios of the new technologies.

Thus, the planner aims to maximize,

$$(4.4.9) \quad \int_0^{\infty} e^{-rt} \left(\int_0^{\infty} \left\{ z_{t,\tau} e^{-r\tau} [g(T_t) f(k_t, n_t) - w_{\tau} n_t] d\tau - C_1(k_t x_t) - C_2(E_t) \right\} dt \right)$$

subject to

$$(4.4.10) \quad \int_0^{\tau} Z_{t,\tau} dt \leq X \quad \forall \tau$$

$$(4.4.11) \quad Z_{t,\tau} \leq X_t \quad \forall \tau \geq t$$

$$(4.4.12) \quad T_t = \int_0^t E_{\tau} d\tau \quad \forall t$$

where $Z_{t,\tau}$ is the amount of land utilized at time τ with technology of vintage t and X_t is the amount of land that was introduced with technology t . Output per acre produced with vintage t is determined by the production function per acre $g(T_t) f(k_t, n_t)$ where k_t and n_t are, respectively, capital per acre and labor per acre of vintage t , and $g(T_t)$ represents the technological change that depends on the stock of knowledge at time t , i.e., T_t . Government research activities at time t are denoted by E_t ; it can be measured by spending on research and development in real terms. From (4.4.4) it determines the rate of change in the stock of technological change, T_t .

Output price is assumed to be given and is used as a numeraire; the price of labor at time τ is W_{τ} . Total costs of private and public investments are, correspondingly, $C_1(X_t k_t)$ and $C_2(E_t)$. We assume $C_i' > 0$ and $C_i'' > 0$ ($i = 1, 2$) in order to take into account the fact that the region faces a rising supply function of credit funds.

The integral in (4.4.1) measures the economic surplus of the region, constraint (4.4.2) represents the potential of land capacity for the region, and constraint (4.4.4) measures the dynamic pattern of accumulation of the stock of knowledge, T_t , that determines the technological shifter of production of vintage t .

Constraint (4.4.3) states that the amount of land used with vintage t should not exceed the amount of land that was introduced with technology of vintage t .

A necessary condition for an optimal solution is

$$\begin{aligned}
 & Z_{t,\tau} = X_t \text{ if } g(T_t) f(k_t, n_t) - W_\tau n_t - \rho_\tau > 0 \\
 (4.4.13) \quad & 0 \leq Z_{t,\tau} \leq X_t \text{ if } g(T_t) f(k_t, n_t) - W_\tau n_t - \rho_\tau = 0 \\
 & Z_{t,\tau} = 0 \quad \text{otherwise,}
 \end{aligned}$$

where ρ_τ is the shadow price of the land constraint (4.4.2) and it can be interpreted as the land rent under competitive conditions. The quasi rent at time τ of capital of vintage t is $g(T_t) f(k_t, n_t) - W_\tau n_t - \rho_\tau$. Condition (4.4.5) states that all the capacity of vintage t will be utilized as long as it yields positive quasi rents, and the vintage will not be utilized when it yields negative quasi rent.

Assuming that revenue increases slower than variable costs (labor + land costs), every vintage has a finite length of life denoted by $a(t)$ which is determined by solving

$$(4.4.14) \quad g(T_t) f(k_t, n_t) - W_{\tau+a(t)} \cdot n_t - \rho_{\tau+a(t)} = 0.$$

Also under these assumptions, $Z_{t,\tau} = X_t$ for $t \leq \tau \leq t + a(t)$, i.e., the land of each vintage (say, vintage t) is operated always at its full capacity.

Assume that the rate of change in W_t is constant and equal to δ , i.e., $\dot{W}_t = \delta W_t$, and define $\tilde{r} = r - \delta$. Incorporating all the above in the necessary conditions for an optimal solution results in:

$$(4.4.15) \quad \left\{ \frac{1 - e^{-ra(t)}}{r} \left[g(T_t) f_k(k_t, n_t) \right] - C'_1(k_t X_t) \right\} X_t = 0$$

$$(4.4.16) \quad \left\{ \frac{1 - e^{-ra(t)}}{r} \left[g(T_t) f_n(k_t, n_t) \right] - w_t \frac{1 - e^{-\tilde{r}a(t)}}{\tilde{r}} \right\} X_t = 0$$

$$(4.4.17) \quad \frac{1 - e^{-ra(t)}}{r} \left[g(T_t) f(k_t, n_t) \right] - w_t n_t \frac{1 - e^{-\tilde{r}a(t)}}{\tilde{r}} - k_t C'_1(k_t X_t) = 0$$

$$(4.4.18) \quad \int_t^{\infty} e^{-r(\tau-t)} X_{\tau} g'(T_{\tau}) f(k_{\tau}, n_{\tau}) \frac{1 - e^{-ra(t)}}{r} d\tau - C'_2(E_2) = 0.$$

Equation (4.4.7) states that the optimal capital/land ratio of vintage t is determined such that the marginal cost of capital is equal to the discounted value of the marginal product of capital throughout the life span of the vintage. From equation (4.4.8) the labor/land ratio of vintage t is determined such that the value of discounted marginal product of labor is equal to the discounted costs of a unit of labor throughout the life span of the vintage.

The next condition in (4.4.9) states that the optimal quantity of land introduced with technology of vintage t is determined by equating the discounted sum of quasi rents per acre to the costs of capital per acre at time t .

Equation (4.4.10) implies that the optimal level of research and development at time t is determined by equating the marginal costs of public funds with the discounted sum of marginal benefits of the stock of knowledge over all vintages introduced after time t .

The analysis of the optimal behavior of agriculture in the region over time indicates that the development process has two stages: (1) the settlement stage when the utilized land base is continuously growing. New capital is introduced mostly with new land, and the land rents are zero. (2) The maturity stage when all the land of the region is utilized. In this stage, new vintages are introduced only to replace obsolete capital goods. If the economic life span of capital goods of different vintages is about the same and the price of capital relative to labor is nonincreasing, then the land rents are increasing throughout the maturity stage.

Two issues of particular interest in the study of the region's behavior over time are the dynamic paths of public investment in R & D and private investment in capital.

The equation of motion of public R & D expenditure is

$$(4.4.19) \quad \dot{E} = \frac{1}{C_2''(E)} \left[-X_t g'(T_t) f(k_t, n_t) \frac{1 - \rho^{-ra(t)}}{r} + r C_2'(E) \right].$$

Condition (4.4.19) indicates that government research will decline (increase) over time if the discounted value of the marginal product of knowledge through the life of a given capital vintage is greater (smaller) than the interest payments on the price of public research.

Moreover, it is proven that, when the discounted value of the marginal product of knowledge is declining over vintages, government research activity will decline over time. Thus, in the early stages of the development process, government will spend significantly to build a base of knowledge, and its research activity is tapering off.

The equation of motion of private investment (where $z_t = k_t X_t$) is given by

$$\frac{dz}{dt} = \frac{1}{C_1''(Z) k} \left[\frac{1 - \rho^{-ra}}{r} g'fE + rk C_1'(Z) - (gf - nw - \rho_t) \right].$$

Private investment is increasing (decreasing) over time as long as gains from technological change and savings from interest payments on private capital investments are greater (smaller) than the loss of quasi rent of private capital resulting from postponing private investment activity.

Suppose public and private investments are financed by the same capital market, i.e., $C(E + kX)$ replaces $C_1(kX) + C_2(E)$ in equation (4.4.1). In this case it is proven that, while public investments are declining over time, private investment tends to grow at early stages and take advantage of the accumulative knowledge but, at a later stage of development, when the marginal productivity becomes small, private investment (like public investments) is tapering off.

4.5. Econometrics

A methodology for estimation of multicrop production functions was introduced in "Estimation of Multi-Crop Production Functions." It was applied for estimation of the production functions of the five main vegetables in Hazeva. The model assumes profit maximization on behalf of farmers and incorporates the first-order conditions with the production function in estimation of the production function parameters. For each crop, constant returns to scale were assumed and Cobb-Douglass production functions were estimated, assuming four inputs: land, water, other purchased inputs, and management; and three multiplicative time shifters.

The data were collected from the Moshav's accounting system supported by data on land allocation from the Extension Service. As is typical with accounting data, the allocations of variable inputs to individual crops are not recorded. Rather, the data include total expenditures or quantities of purchased inputs. Total revenues and quantities of outputs and land allocations are also observed. Specifically, the data are a combined cross-section and time series yielding annual observations for 1977-1980 that include:

(a) Cultivated area, production, and revenue by crop for tomatoes, bell peppers, onions, melons, and eggplants. Almost all farmers grow tomatoes, bell peppers, and melons while a smaller number also grow eggplants and onions.

(b) Aggregate water input and expenditure. The arid conditions and remoteness of outside water resources make water one of the most critical inputs in the production process. Drip irrigation, which makes very efficient use of water, is the dominant irrigation technology.

(c) Other purchased input expenses. These include variable costs associated with inputs such as fertilizer, pesticides, and cultivating materials measured in 1980 prices. For purposes of estimation, these data are used to construct an index of "other variable input use."

(d) Management ability. To reflect differences in human capital, a Delphi panel was assembled from farm advisors and settlement leaders and asked to assess management ability of individual farmers. The variable is a rating from 1 to 10 representing a consensus of the panel.

Using this data set, equations were estimated by nonlinear two-stage and three-stage least squares assuming constant returns to scale. No problems were experienced with convergence presumably due to the near-linearity of the model. The results are reported in Table 2. The results of the two estimation methods are quite similar. All coefficients have right signs and most have quite reasonable magnitudes. Except for tomatoes and melons, all of the water production elasticities are between .05 and .08; all of the other purchased input elasticities are between .22 and .44; and all implied non-purchased (land-labor-capital) production elasticities are between .51 and .70. The tomato and melon production functions imply much less importance of purchased inputs. And, indeed, tomatoes are considered to be relatively more labor intensive, and melons are considered to be a residual crop that is relatively more land intensive.

Both estimates show that human capital has a significant effect on production of at least one of the crops. The greatest significance in the N3SLS results is for the three crops (tomatoes, bell peppers, and melons) that are grown by most farmers. One explanation for why human capital does not explain significant differences in onion and eggplant production is that only the best farmers successfully produce those crops.

Significant (neutral) technological change is suggested for the two most important crops also. That is, since the constant term corresponds to 1980, the shift terms suggest a significant positive trend with annual weather variations for both tomatoes and bell peppers.

TABLE 2
Estimated Model

Equation/coefficient	Two-stage		Three-stage	
	least squares		least squares	
	Estimate	t-Ratio	Estimate	t-Ratio
<u>Tomato Production Function</u>				
Constant term	7.545	10.56	8.623	13.27
Water elasticity	0.0374	2.78	0.0214	1.91
Other purchased input elasticity	0.0865	1.49	0.0173	0.34
Management	0.0585	1.73	0.3772	1.31
1977 shift	-0.2254	- 2.52	-0.2248	- 2.95
1978 shift	-0.398	- 0.46	-0.0075	- 0.13
1979 shift	-0.2066	- 2.47	-0.2732	- 3.82
<u>Bell Pepper Production Function</u>				
Constant term	4.679	12.94	4.534	13.64
Water elasticity	0.0457	7.14	0.0509	9.32
Other purchased input elasticity	0.2905	9.12	0.3087	11.01
Management	0.0583	2.86	0.0246	1.45
1977 shift	-0.5084	-10.39	-0.5505	-13.23
1978 shift	-0.5470	-11.44	-0.5175	-12.61
1979 shift	-0.2839	- 5.64	-0.2708	- 6.84

(Continued on next page.)

TABLE 2--continued.

Equation/coefficient	Two-stage		Three-stage	
	least squares		least squares	
	Estimate	t-Ratio	Estimate	t-Ratio
<u>Onion Production Function</u>				
Constant term	2.888	2.79	2.4960	2.49
Water elasticity	0.0509	3.49	0.0551	4.28
Other purchased input elasticity	0.3970	4.34	0.4309	5.04
Management	0.0409	1.01	0.0200	0.61
1977 shift	0.3757	4.04	0.4975	7.23
1978 shift	0.3426	2.23	0.3768	3.13
1979 shift	0.3722	3.32	0.4463	5.14
<u>Melon Production Function</u>				
Constant term	6.368	22.40	6.196	24.87
Water elasticity	0.0049	1.29	0.0085	2.64
Other purchased input elasticity	0.0714	3.52	0.0807	4.39
Management	0.0507	1.03	0.0624	1.73
1977 shift	-0.0844	- 0.64	-0.0329	0.34
1978 shift	0.2826	2.66	0.2060	2.67
1979 shift	-0.0391	- 0.33	-0.0083	- 0.1

(Continued on next page.)

TABLE 2--continued.

Equation/coefficient	Two-stage		Three-stage	
	least squares		least squares	
	Estimate	t-Ratio	Estimate	t-Ratio
<u>Eggplant Production Function</u>				
Constant term	4.817	7.52	4.840	7.83
Water elasticity	0.0788	8.64	0.0776	9.57
Other purchased input elasticity	0.2225	4.18	0.2233	4.51
Management	0.0849	2.21	0.0310	0.96
1977 shift	-0.0858	-0.75	-0.0172	-0.18
1978 shift	0.1203	1.18	0.3128	3.66
1979 shift	0.2396	-2.04	0.0305	0.33
<u>Constant term of equation (24)</u>				
k = bell peppers, κ = tomatoes	2.026	16.39	2.1984	21.29
k = onions, κ = tomatoes	2.0776	9.11	2.3160	10.74
k = melons, κ = tomatoes	1.9227	15.57	2.0937	19.97
k = eggplants, κ = tomatoes	1.0054	7.68	1.1093	8.92

4.6. Extensions

As was pointed out in the Second Annual Technical Report [1981], two related works were carried out within this project. First, even though the mean-variance approach has a sound empirical justification, limitations of such an approach motivated an investigation of related topics which are summarized in the paper, "Approximation of Expected Returns and Optimal Decisions under Uncertainty Using Mean and Mean-Absolute Deviation" [1983].

This paper deals with economic models in which (a) the expectation of a function of random variables has to be approximated in terms of simple parameters of the distribution, and (b) returns, as well as optimal decisions, are to be approximated for decision problems under uncertainty. The innovative aspect of this paper is the introduction of approximations based on mean and mean absolute deviation (MAD) which replaces the traditional mean variance. The general results are applied to firms facing uncertainty, either in output or in prices.

One of the main motivations in using the mean-MAD rather than the mean variance is the capability of dealing with problems of uncertainty where the random variables do not possess a finite variance, in particular, the family of stable distributions.

For example, one of the results obtained is that a production risk indicator depending on the elasticity of the marginal rate of substitution of variable inputs for fixed inputs with respect to output determines whether a firm will invest or disinvest in fixed assets under more risky conditions.

While studying the problem of agricultural planning with rigidities in production, a second conceptual problem was raised, though, in the different

field of optimal exploitation of energy resources. It is summarized in the paper, "Optimal Exploitation of Energy Resources: Solar Power and Electricity Generation in Below Sea Level Basins" [1982].

This paper analyzes the generation of hydroelectric power by the transfer of seawater to locations which are significantly below sea level (e.g., the Dead Sea in Israel and the Qatara depression in Egypt) combined with solar energy that via evaporation will perpetuate the hydroelectric power capacity.

Two paradigms are depicted: the first focuses on optimal planning of the canal capacity and optimal use of its water to generate hydroelectric power while filling the basin to its steady-state level. The second paradigm includes the impact of solar pools as a new technology whose date of adoption is a random event.

It is shown that the optimal flow of water through the canal depends on the relationship between optimal canal capacity and the rate of water evaporation in the basin. The optimal design of the canal project can be considered as a hybrid between optimal depletion of a natural resource (the use of height differences by filling up the basin) and a renewable resource (the use of solar energy to evaporate the basin water).

The optimal policy is shown to consist of alternative intervals, some of which may vanish under certain conditions: first, the operation of the canal at full capacity; then gradual decrease of water flow at the rate which is equal to the elasticity of the marginal product of electricity generation times the sum of interest rate and the marginal evaporation rate; and, finally, the stabilization of the water flow at the rate of steady-state evaporation. The solution for the stochastic model with solar pools technology as a random event is formulated as a two-stage maximization problem. It

is shown that, in contrast to the first paradigm, the canal may start to operate with underutilization of capacity in the first period. In this case, too, the quantity of water flowing through the canal is a nonincreasing monotonic function over time with a jump to increase the quantity of water at the date the solar pools are introduced.

5.1. Evaluation of the Research Achievement With Respect to the Original Research Proposal

The results of this research were pointed out in the previous technical reports, First Annual Technical Report [1980] and Second Annual Technical Report [1981], as well as in section 4 of this final technical report. In the original research proposal, we focused first on the concepts of putty clay in the context of agricultural production and planning and considered adoption of the aggregation procedures suggested by Johansen.

As our research progressed, we recognized the need to broaden and change our conceptual approach to the problems confronting the planner in an arid zone. Thus, the putty clay approach was accommodated to include a Sato-type production function that introduces a certain degree of substitutability between factors of production and outputs within the rigid putty clay model.

At a later stage, while collecting the data and starting its analysis, it became evident that the importance of human capital quality and uncertainty in production as well as in other agricultural economic phenomena are of paramount importance. Thus, we included these two factors both in the conceptual and empirical analysis.

Another important topic that has been considered beyond the initial scope of the research proposal is the subject of agricultural policy, especially with regard to allocation of land and development and adoption of new technologies.

As was pointed out above, a major thrust in our efforts was devoted to the collection and construction of a data base. In our original research proposal, we did not foresee the amount of time and resources needed. We encountered many problems in identifying and collecting accounting data on farms and settlements in the Arava region. Moreover, while farmers allocate most inputs between specific production activities, the accounting data does not observe these allocations. Hence, appropriate procedures were needed in order to generate the disaggregation of inputs so that they can be allocated to the specific crops.

The scope of the empirical work resulted in concentrating in the Arava region. And at this stage we carried the analysis of the data collected only for vegetable crops, which is the main activity in the Moshavim villages. However, the extended and unique data base that was generated is the basis for a new BARD proposal for the next two years, "Aggregation in Regional Agricultural Planning: The Role of Human Capital and Risk."

6.1. Description and Results of Cooperation

This project was conducted in close cooperation between the Israeli and the American teams. During the first year and a half, Hochman, from the Israeli team, worked in the United States in close cooperation with the American team. Vitkan supervised the collection of data in Israel. The two teams spent several months in the Arava; the American scholars visiting twice for periods of 3-4 weeks. The cooperative efforts of the teams in these visits were devoted to identifying the problems and documenting the information and to interviewing key policy and extension people as well as leaders in the farmers' community.

During the second half of the period the data base was constructed; econometric studies were conducted; and the empirical results obtained were

fed back to the regional planners, farm advisers, and farmers. Last year a one-day meeting with the people of the Department of Settlement of the Hebrew Agency and the representatives of the two leading Moshavim in the region was held in Beer-Sheva in which both teams were represented.

Throughout the period, joint and separate conceptual work was done with semiannual workshop meetings.

7.1. Thesis

An M. A. dissertation, "A Mean-Variance Analysis of the Optimal Mix of Vegetable Crops Production in Ein-Yahav," is completed by Orit Kohen at the Department of Economics in Ben-Gurion University at the Negev, supported by the BARD 1-79-10 project.

8.1. Inventions

Not applicable.

9.1. Publications

Eithan Hochman and Aaron Ben-Tal, "Approximation of Expected Returns and Optimal Decisions Under Uncertainty Using Mean and Mean-Absolute Value Deviation," Working Paper, Ben-Gurion University of the Negev, Beer-Sheva, Israel, 1982.

Eithan Hochman, Oded Hochman, and David Zilberman, "A Dynamic Model of Regional Development with Production Rigidities and Public Research and Development," Working Paper, Ben-Gurion University of the Negev, Beer-Sheva, Israel.

Eithan Hochman and David Zilberman, "Optimal Exploitation of Energy Resources: Solar Power and Electricity Generation in Below Sea Level Basins," Journal of Environmental Economics and Management (forthcoming).

Eithan Hochman, Richard E. Just, and David Zilberman, "The Dynamics of Agricultural Settlement of Sparsely Populated Environment: The Case of the Arava Region in Israel," in Resources and Development in Sparsely Populated Arid Environment (to be published by Westview Press).

Eithan Hochman, Gideon Vitkan, and David Zilberman, "The Settlement of the Arava Region in Israel," Ben-Gurion University of the Negev, Beer-Sheva, Israel, March, 1983.

Richard E. Just and David Zilberman, "Stochastic Structure, Farm Size, and Technological Adoption in Developing Countries," Oxford Economic Papers (forthcoming).

Richard E. Just, Gordon C. Rausser, and David Zilberman, "Modeling Efficiency and Equity in Agricultural Production Systems," Equity and Efficiency Proceedings of the 19th International Conference of Agricultural Economists.

Richard E. Just, David Zilberman, and Eithan Hochman, "Estimation of Multicrop Production Functions," submitted to American Journal of Agricultural Economics.