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Estimation of Farmers' Risk Attitude: An Econometric Approach

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Abstract

An econometric procedure for estimating Arrow-Pratt coefficients of risk aversion is derived. The model, of farmers allocating land among different crops and time between leisure and labor, allows for testing Arrow's hypotheses of decreasing absolute risk aversion and increasing relative risk aversion. The empirical results support these hypotheses.

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Introduction

The seminal works of Arrow (1971) and Pratt (1964) established that under the expected-utility hypothesis, there exist one-to-one relationships between preferences over random income or wealth and the measures of risk aversion. Since then, the various measures of risk aversion have played a central role in determining comparative static results of behavior under uncertainty (i.e. Sandmo; Just and Zilberman). In particular, specific assumptions regarding the signs, magnitudes, and behaviors with respect to wealth changes of the measures are required. To date, most theoretical studies have used Arrow's hypotheses on the effect of wealth on the measures of risk aversion (i.e. decreasing absolute and increasing relative risk aversions). There is, however, little empirical evidence on the signs and magnitudes of these measures, and even less on the effect of wealth changes on them. Thus, the objective of this paper is to estimate the magnitude of the measures of risk aversion, as well as the effects of wealth changes on them, thereby testing Arrow's conjectures about the behavior of the measures with respect to income or wealth changes.

A large body of evidence against the expected utility hypothesis has been accumulating over the past decades (i.e. Machina, 1987), raising some doubts as to the importance of the previously mentioned measures. Most of the violations of the expected utility hypothesis, however, have been obtained with via carefully planned experiments. Thus, it is unclear whether such violations should prohibit the use of the expected utility hypothesis when studying real-world decisions. Recently, Bar-Shira (1992) could find no violations of the expected utility hypothesis in production decisions of Israeli farmers. Rubinstein (1988) argued that the expected utility hypothesis is likely to be violated when alternatives are similar. Buschena and Zilberman (1992) supported Rubinstain's argument empirically. However, alternatives arising in real life appear to be far from similar. These, in general, validate the use of the expected utility hypothesis in empirical studies, as is done in this paper. Further, the current study employs the same data used by Bar-Shira (1992), which, as mentioned earlier, have been proven to obey the expected utility model.

This paper proceeds as follows. The first section reviews the relevant literature. The second discusses the relationships between the absolute, relative and partial measures of risk aversion, and their theoretical responses to changes in income or wealth. The third section outlines the model and derives some conclusions on the effect of risk on production. The fourth section gives empirical background and describes the data. In the fifth section, the estimation procedure is outlined. The sixth section presents the results and compares them to results which have been obtained in other studies. The paper concludes with a short summary and conclusions.

Relevant Literature

The literature has attempted to provide empirical evidence of individuals' risk attitudes. These attempts were initiated by experimental psychologists who conducted laboratory experiments in which a series of hypothetical questions concerning choice between risky alternatives was presented, for example, to a class of students (i.e. Kahneman and Tversky). These experiments were designed such that the only factor affecting the decision-maker was his risk attitude, thereby isolating the effect of risk from other factors that may influence the decision in real-world situations. In economics, these attempts have been made mostly in the agricultural sector, where the individual's risk attitude has very important policy implications. Dillon and Scandizzp (1978) used the experimental approach to elicit risk attitudes of subsistence farmers in northeast Brazil.

The main disadvantage of the experimental approach is that the individuals might not have the incentive to reveal their true preferences. To overcome this disadvantage, Binswanger (1980, 1981, and Quizon et al. 1984) conducted a fairly large-scale experiment in rural India. Unlike experimental approaches using hypothetical payments, Binswanger used payments that were both real and significant, the highest expected payoff for a single decision exceeding the monthly income of an unskilled worker. However, even this approach is not free of disadvantages, since the individuals might have utility from the gamble itself, and they might have a preference for particular probabilities.

The econometric approach presents neither of the above disadvantages, because it uses the actual decisions made by the individuals. Moscardi and de Janvry (1977) used such an approach, in which the decision-makers followed the safety-first rule.[1] Antle (1987, 1989), Bardsley and Harris (1987), Love and Buccola (1991), and Pope and Just (1991) used an econometric approach to study of risk attitudes in decision-makers which were

[1] Binswanger shows that predictions derived from these models are inconsistent with experimental behavior.

expected utility maximizers. Newbery and Stiglitz (1981), Robison (1982), Pope (1982), Hazell (1982) and Binswanger (1982) present a comprehensive discussion of the relevant literature. We will now discuss more closely related works in which econometric approaches utilized.

Antle (1987) suggested a general model in which technology and risk attitude distribution are estimated sequentially. The model used the joint distribution of profits and risk attitudes in a producer population to estimate the moments of the risk attitude distribution. Estimation of the model was feasible via the *generalized method of moments.* For empirical purposes however, a moment-based approach was applied to Indian data. Love and Buccola took this model a step further. They estimated the technology and risk attitude parameters simultaneously, thereby avoiding inefficiencies and inconsistencies. Neither study, however, empirically tested the effects of changes in wealth or income on the measures of risk aversion.

Bardsley and Harris developed a simple model relating debts and assets portfolio choices of the farm. The production decision was made implicitly by choosing the optimal mean variance combination on the efficiency frontier. Bardsley and Harris applied their model to Australian grazing data, to examine the behavior of the partial risk aversion coefficient under changes in wealth and income. Pope and Just developed a test for distinguishing between constant absolute, relative, and partial risk aversions. They implemented the test to potato supply response in Idaho. Constant absolute and partial risk aversions were rejected whereas constant relative risk aversion was not. Niether model, however, allowed direct conclusions on the effects of wealth changes on the measures of absolute and relative risk aversions.

Antle (1989) discussed structural versus nonstructural econometric approaches. The former uses optimizing conditions of input choice to estimate both technology and risk attitude, whereas the nonstructural approach uses the distribution of net returns to estimate the risk attitude only. Structural modeling requires more data and more assumptions, but gives more information than nonstructural modeling. The choice depends on the needs: if interest is in policy analysis, structural modeling should be used; if interest is in risk attitude per se, nonstructural modeling is preferred. Further, one should be aware that when modeling structural real-life situations with a nonstructural model, risk and other factors affecting the decision process are collapsed into the risk factor. Thus, nonstructural modeling may yield biased estimates of the risk attitude, the problem which initiated the experimental approaches. In a sense, the model presented here can be viewed as a combination of both approaches. It requires only general data, but still allows for some behavioral inference and separation of risk and other factors affecting the decision process.

Another relevant concern is variation in the risk measure which is likely to occur over the sample space. This variation can come from one or more of the following sources: i) variation of risk attitude among individuals, namely, interpersonal changes; ii) variation of risk attitude over time, namely, intrapersonal changes; and iii) variation of wealth, when the estimated measure is not constant. Antle assumed a random utility approach to accommodate variation in risk attitude over time and individuals, whereas Bardsley and Harris explained variation in risk attitude by wealth changes. We explain changes in risk attitudes by wealth changes under the maintained hypothesis that all individuals have the same risk attitude. In other words, variation in risk attitude is explained by movement along the utility function rather than by movement of the utility function. Some of the empirical work (Dillon and Scandizzp; Moscardi and de Janvry; Binswanger) concerning elicitation of risk attitudes has tried to relate variation in risk attitude to variation in socioeconomic characteristics among individuals or over time. The success of those attempts should not necessarily be interpreted in favor of the random utility approach. In some situations, it is quite reasonable to assume that differences in socioeconomic characteristics among individuals will affect the individual's wealth level and thus his risk attitude, rather than directly affecting the risk attitude. In the case studied here, the empirical background suggests similarities between individuals. However, differences in wealth are observed. Thus, as suggested by the theory, we consider wealth as a primary factor affecting risk attitude, while differences in individuals' preferences over monetary outcomes are assumed to be negligible. Empirical evidence supporting the assumption of homogeneous risk attitudes is given by Antle (1989) who writes "One interpretation of these results is that risk attitudes are homogeneous within villages."

Measures of Risk Aversion: Properties and Relationships

Arrow and Pratt first introduced the measure of absolute risk aversion

$$A(W) \equiv -U''(W)/U'(W), \tag{1}$$

where W indicates total wealth and U'' and U' indicate the second and first derivatives of the von Neumann-Morgenstern utility function, respectively. The measure of absolute risk aversion is appropriate to describe situations in which total wealth has a fixed stochastic part – income, and a variable nonstochastic part – initial wealth. Arrow pointed out that it is natural to hypothesize that the individual's willingness to undertake a certain risky project is greater when he/she is wealthier. In other words, wealthier individuals should have a greater amount of risky assets in their portfolio. Thus, the measure of absolute risk aversion should decrease with wealth. To further illustrate this, it is useful to consider the risk premium. Pratt, and Menezes and Hanson showed, by different methods, that if the measure of absolute risk aversion is decreasing (increasing) with wealth, then the risk premium is decreasing (increasing) with wealth. Economically this means that the wealthier the individual, the smaller the maximum amount he will pay for insurance against fixed risk.

In situations where both the stochastic and nonstochastic components of the wealth are changing proportionally the appropriate measure is the measure of relative risk aversion

$$R(W) \equiv -(U''(W)\ U'(W))W. \tag{2}$$

Arrow's hypothesis is that when both initial wealth and the risky project are increased by the same proportion, the individual's willingness to undertake the risky project is smaller. In other words, wealthier individuals should hold a smaller proportion of risky assets in their portfolio. For this case, Pratt, and Menezes and Hanson showed that proportional increases in both wealth and income result in a more than proportional increase (decrease) in the risk premium if the measure of relative risk aversion is increasing (decreasing) with wealth. The intuitive hypothesis of increasing relative risk aversion is also supported mathematically. Assuming bounded utility functions,[2] Arrow showed that the measure of relative risk aversion must be greater than unity for arbitrarily large wealth, and less than unity for arbitrarily small wealth.[3] Thus, a continuous monotone measure of relative risk aversion must be increasing with wealth and must equal one for some wealth between zero and infinity. Another difference between the two measures is that while the measure of relative risk aversion is a pure number, the measure of absolute risk aversion is affected by the wealth units. Consequently, the former is universally comparable between different studies whereas the latter is not.

The third measure of risk aversion being considered is the measure of partial risk aversion (Menezes and Hanson; Zeckhauser and Keeler)

$$P(W_0, \pi) \equiv -(U''(W_0 + \pi)\ U'(W_0 + \pi))\pi, \tag{3}$$

where W_0 denotes nonstochastic initial wealth and π denotes stochastic income. Like the measure of relative risk aversion, this measure is unitless. The measure of partial risk aversion is appropriate to describe situations in which initial wealth is fixed and income is changed proportionally. In this case, there is a one-to-one relationship between the risk premium and the measure of partial risk aversion, increasing partial risk aversion implies

[2] The bounded utility assumption is necessary to eliminate what is known as the St. Petersburg paradox (Laffont 1989. pp. 7-8).

[3] Relative risk as $\bar{R}$, and then integrating twice the expression $U''/U' > -\bar{R}\, W$.

that a proportional increase in risky income would result in a more than proportional increase in the risk premium. Below, the behavior of the measure of partial risk aversion under wealth changes or risky income changes is shown to be determined by the measures of absolute and relative risk aversion, when the measure of relative risk aversion is increasing with wealth.

The measure of partial risk aversion is related to the measure of absolute risk aversion as follows:

$$P(W_0, \pi) = A(W_0 + \pi)\pi. \tag{4}$$

Differentiating both sides with respect to W_0 gives

$$\frac{\partial P}{\partial W_0} = A'\pi. \tag{5}$$

Hence decreasing absolute risk aversion implies decreasing partial risk aversion with respect to initial wealth. The measure of partial risk aversion is also related to the measure of relative risk aversion by

$$P(W_0, \pi) = R(W_0 + \pi)\frac{\pi}{W_0 + \pi}. \tag{6}$$

Differentiating both sides with respect to π yields

$$\frac{\partial P}{\partial \pi} = R'\frac{\pi}{W_0 + \pi} + R\frac{W_0}{(W_0 + \pi)^2}. \tag{7}$$

Hence increasing relative risk aversion implies increasing partial risk aversion with respect to π. The opposite, however, does not hold. One may have increasing partial risk aversion with respect to π and decreasing relative risk aversion at the same time.

The above discussion shows that information concerning the behavior of the measures of absolute and relative risk aversion (when the latter is increasing) is sufficient to determine the behavior of the measure of partial risk aversion, but not the opposite (Bar-Shira, 1991). We now show that the elasticity of the measure of absolute risk aversion with respect to wealth determines the behavior of both measures of absolute and relative risk aversion (Bar-Shira, 1991). The elasticity of the measure of absolute risk aversion with respect to wealth is defined as

$$\epsilon_W^A \equiv A' \frac{W}{A}. \tag{8}$$

Assuming risk aversion, this elasticity is negative (zero, positive) when the measure of absolute risk aversion is decreasing (constant, increasing). In addition, because $R' = A'W + A > 0$ if and only if $\epsilon_W^A > -1$, the measure of relative risk aversion is increasing (decreasing) when the elasticity of absolute risk aversion is greater (smaller) than minus one. It follows that $0 > \epsilon_W^A > -1$ is equivalent to decreasing absolute risk aversion and increasing relative risk aversion. Note, that when $\epsilon_W^A = -1$, the measure of relative risk aversion is constant. The analysis in this section shows that the elasticity of the measure of absolute risk aversion with respect to wealth determines the behavior of all three measures of risk aversion.

Methodology

The model presented below describes a real-life situation: I small farm owners, who form a village, are allocating a fixed amount of land $\bar{L}$ among agricultural activities, each having net return π_j; and a fixed amount of time $\bar{T}$ among leisure T_l and farm work. The technology is assumed to be a von Liebig one. Whereas generally this assumption is restrictive, it is appropriate for the present case. The plausibility of the constant return to scale assumption is due to the fact that the total scale of the farm is constant, because of either the time or land constraint. It follows that increasing one activity must be accompanied by a decrease in another activity, leading to reallocation of all inputs, including managerial input. Thus, the increase in size of some activities can be effected without the loss of efficiency usually caused by increasing all inputs but the managerial one. The technology assumption is further justified by Just *et al.*

Furthermore, labor is also a scarce input because hired labor is not available and all labor input to the farm has to be supplied by the owner and his family. Although in this study the absence of a labor market is due to the fact that farmers obey the principle of *self-employment*,[4] absence of a labor market is a typical situation in developing countries. The absence of a labor market emphasizes the importance of time allocation between leisure and agricultural activities in the decision process.

Farmers derive utility from both monetary wealth and leisure, so that their objective function is a two-argument utility function. By choosing different land allocations, the farmers are choosing different lotteries. In this sense the farmer's problem is the same as the investor's problem, the latter having to decide on their asset portfolio. Each farmer is assumed to act as an expected utility maximizer, and his decision problem can be written as

$$\max_{L,T_l} E[U(W,T_l)] = \max_{L,T_l} E[U(W_0 + \pi' L, T_l)] \tag{9}$$

subject to:

$$\bar{T} - \sum_{j=1}^{J} T_j L_j = T_l \tag{9.a}$$

$$\sum_{j=1}^{J} L_j \leq \bar{L} \tag{9.b}$$

where L is a vector of the land allocated to J crops, π is a vector of net returns, W_0, and W denote the same as before, T is a vector whose typical element T_j is the time required to cultivate one unit of land planted with crop j, and E is the expectation over the distribution of profits. The first constraint (9.a) is the time constraint: it says that the total amount of available time minus time spent on farm activities equals to time devoted to leisure. The second constraint (9.b) is the capacity constraint, which says that the total cultivated land is less than or equal to the total amount of available land.

[4] The self-employment principle is one of the five principles which define a Moshav – an agricultural settlement in Israel (for more details see Zusman).

Substitute the time constraint (9.a) into the objective function (9) and assume that the capacity constraint (9.b) is not binding.[5] Then, the first-order conditions are

$$\frac{\partial E[U]}{\partial L} = E[\pi \cdot U_1] - E[T \cdot U_2] = 0 \tag{10}$$

where U_1 and U_2 are the partial derivatives with respect to the first and second arguments, respectively.

The interpretation of the first-order condition is straightforward: one more unit of time allocated to either leisure or one of the crops will generate, on average, the same utility increase. Thus, in the absence of a labor market, the cost of labor is determined by its opportunity cost in terms of leisure. In addition, the cost of labor is endogenous to the decision-maker, and hence the optimal production scheme is different from the optimal decision when the cost of labor is exogenous (as in a situation where hired labor is available).

Another factor that affects the optimal decision is risk. Following Sandmo (1971), it can be shown that $(\bar{\pi}_j/T_j) \cdot U_1 > U_2$ for a risk-averse individual. Thus, in the case of decreasing marginal utility from leisure, the individual consumes more leisure under uncertainty than under certainty. Furthermore, in this model under certainty, the individual grows only one crop, the crop for which the profit per unit of time is maximum, and leisure is consumed to the point where its marginal utility is equal to the marginal utility from one more unit of time allocated to the chosen crop. Under uncertainty however, the farmer grows more than one crop, and leisure is consumed to the point where its marginal utility is less than the marginal utility from the lowest profit per unit of time. Thus, it appears that risk-averse farmers diversify risks by choosing a crop portfolio. This led researchers to model the choice of crop portfolio as choice of asset portfolio. Generally, the approach

[5] Note that in this study, the observed land allocations sum to less than the total land, $\bar{L}$.

is to find the efficient frontier in the mean-variance plane by quadratic programming, and then to deduce the magnitude of the risk-aversion coefficient from the slope of the frontier at the chosen point. The econometric estimation approach has the advantage of allowing better statistical inferences.

A Taylor series expansion of U_1 around expected wealth, $\bar{W} = W_0 + \bar{\pi}'L$ (where $\bar{\pi} = E[\pi]$), for non-random leisure yields

$$U_1 = \bar{U}_1 + \bar{U}_{1,1}(\pi - \bar{\pi})'L = \bar{U}_1[1 + \frac{\bar{U}_{1,1}}{\bar{U}_1}(\pi - \bar{\pi})'L] \tag{11}$$

where $\bar{U}_1$ and $\bar{U}_{1,1}$ are U_1 and $U_{1,1}$ evaluated at $\bar{W}$, respectively. Substituting (11) into (10) and dividing by $\bar{U}_1$ gives

$$\bar{\pi} - T\frac{\bar{U}_2}{\bar{U}_1} + \frac{\bar{U}_{1,1}}{\bar{U}_1}E[\pi(\pi - \bar{\pi})']L = 0, \tag{12}$$

$$= \bar{\pi} - T\frac{\bar{U}_2}{\bar{U}_1} + \frac{\bar{U}_{1,1}}{\bar{U}_1}\Phi L = 0$$

where Φ is the covariance matrix of net profits from each crop. It is worth mentioning that $T\bar{U}_2/\bar{U}_1$ represents the implicit cost of labor per unit of land.[6] The implicit cost of labor reflects the opportunity cost of time in terms of leisure, translated to monetary worth by the marginal rate of substitution between leisure and money. In this form, the first-order conditions are identical to the usual optimality conditions under uncertainty, where profits minus costs are equated to the risk premium.

Now let the measure of absolute risk aversion, A, vary with W

$$A \equiv -\frac{\bar{U}_{1,1}}{\bar{U}_1} = A(\bar{W}). \tag{13}$$

An unrestricting functional form is: $A = \alpha \bar{W}^{\beta}$, which has the advantage of not imposing risk-seeking or risk-averse behavior and allowing nonlinear changes in the risk attitude with

[6] Note that the units of of $T\frac{\bar{U}_2}{\bar{U}_1}$ are $\frac{time}{land}\frac{utility}{time}/\frac{utility}{money} = \frac{money}{land}$.

respect to wealth. α greater than (smaller than) zero implies risk aversion (risk seeking). β, is the elasticity of absolute risk aversion with respect to W, that is

$$\frac{\partial A}{\partial W}\frac{W}{A} = \beta. \tag{14}$$

As demonstrated above, β determines the behavior of the measures of risk aversion with respect to changes in wealth. Substituting the functional form for the measure of absolute risk aversion into the first order conditions gives

$$\bar{\pi} - T\frac{\bar{U}_2}{\bar{U}_1} - \alpha\bar{W}^{\beta}\Phi L = 0, \tag{15}$$

which, after some algebraic manipulations, can be written as

$$\Phi L = \frac{1}{\alpha}\bar{W}^{-\beta}(\bar{\pi} - T\frac{\bar{U}_2}{\bar{U}_1}). \tag{16}$$

Since L is observed directly and Φ and $\bar{\pi}$ can be estimated from the available data, this relationship would be estimable if $\bar{W}$ and $T\bar{U}_2/\bar{U}_1$ were directly observable. To overcome this problem, one needs estimates for W_0 and T. We assume that the individuals follow a linear consumption function, hence their saving is proportional to their profit. As a consequence, the initial wealth at each time point is the sum of all past profits multiplied by the marginal propensity to save. Formally

$$W_{0,t} = \sum_{i=1}^{t-1}(1+r)^{t-i}b \cdot (\pi' L)_i, \tag{17}$$

where r is the interest rate and b is the marginal propensity to save. Furthermore, we approximate profits that have occurred up to 15 years before the beginning of the data set, by the mean of all available profits.

Let the profit minus implicit cost of labor be defined as net benefit; then it can be expressed as:

$$\bar{\pi} - T\frac{\bar{U}_2}{\bar{U}_1} = \bar{\pi}^{\mu}, \tag{18}$$

where μ is the elasticity of net benefit with respect to profit. Now let μ vary with the farmer's characteristics. That is: $\mu = \sum \psi_i c_i$, where c_i is the ith characteristic and ψ_i is the corresponding coefficient. Replacing μ with the linear combination of characteristics, equation (18) becomes:

$$T\frac{\bar{U}_2}{U_1} = \bar{\pi} - \bar{\pi}^{(\sum \psi_i c_i)}. \tag{19}$$

Substitution of equation (19) into equation (16) yields the estimable functional form

$$\Phi L = \frac{1}{\alpha}\left(W_0 + \bar{\pi}' L\right)^{-\beta} \cdot \bar{\pi}^{(\sum \psi_i c_i)}. \tag{20}$$

Taking the natural logarithm of both sides yields

$$ln\Phi L = ln\frac{1}{\alpha} - \beta ln\left(W_0 + \bar{\pi}' L\right) + \sum \psi_i \cdot c_i \cdot ln\bar{\pi} + \epsilon, \tag{21}$$

where ϵ is a random disturbance reflecting measurement errors in the data.

Empirical Background and Data

The methodology presented in the previous section was applied to estimating the risk attitudes of individual farmers in southern Israel. Data were collected by the accounting office of Moshav Ein-Yahav. This cooperative settlement is located in the Arava region of Israel. The Arava encompasses the plains between the Red Sea and the Dead Sea. It is an arid region with low minimum and high maximum temperatures, making it an off-season producer of vegetables for local and export markets. Other than a handful of additional settlements, the Arava region is not very populated. Each farm on the moshav is privately controlled, and its economic life depends on its profitability. Output marketing and input purchasing are done cooperatively because of scale advantages. The moshav members accept the principles of self-employment and mutual collaboration as their ideological basis. The social behavioral norms in this kind of settlement are very stringent, new candidates for membership have to meet these norms, and the majority of the members have to approve their admittance. The strictness of these rules leads to a very homogeneous population in terms of preferences. Hence it is reasonable to consider the differences in preferences as a secondary (and differences in wealth as the primary) factor affecting risk attitude.

The data set has two parts. The first contains socioeconomic variables in the following order: diligence, thrift, management, experience, spouse work, agricultural knowledge, motivation, land quality, education, and risk seeking. These variables describing farmer characteristics were constructed by means of a Delphi panel assembled from among the moshav leaders and farm advisors. The variables are rated from one to five and represent the consensus of the panel. The higher the number, the better the attribute, for example the better the management ability, the higher the land quality, or the greater the spousal contribution. The second part of the data set contains a cross-section time series sample on 101 farmers over 10 years (1973-1982). It contains aggregated variables consisting of total water use, total water cost, and expenditure on other inputs such as pesticides, fertilizers, and cultivating materials. The arid conditions and the remoteness of any outside water source make water the most critical input. Thus, drip irrigation, a very efficient way of using water, is the dominant technology. Disaggregated data on cultivated land, yield, and revenue are available by crop for bell peppers, tomatoes, onions, eggplants, and melons. Almost all farmers grow tomatoes, bell peppers and melons. A smaller number also grow eggplants and onions. The accounting office, in most cases, does not record input expenditure by crop, but it does record total input expenditure. One can use a behavioristic approach to recover the input expenditure per crop (Just *et al.*), and then to recover the profit for each crop per unit of land. Two main factors cause the opportunity cost of land to be zero. First, there is no market for land because the land is owned by the government, and renting or selling it is illegal. Second, the land is allocated to the farmer in sufficient amount, such that the self-employment principle binds the time constraint before the land constraint becomes binding.

The Estimation

The decision process is based on subjective expectations of future profit, as well as on expected variance of future profit. Future profit expectations are based on the previous year's profits, when these data are available. There are very likely to be some missing values, since no farmer grows every crop, every year. A farmer who has such missing values may use estimated values to form his future profit expectation. The estimated values are based on all available information. That is, the farmer may look at profit of farms which are similar to his/her own in terms of size, location, and owner's wealth, and then decide what profit would have been made. One can estimate past profit missing values by regressing profit on year and farmer dummies. That is

$$\pi_{i,t} = \sum_{i=1}^{T} \gamma_i^y \delta_i^y + \sum_{i=1}^{I} \gamma_i^f \delta_i^f. \tag{22}$$

Then, the estimated profit value is

$$\hat{\pi}_{i,t} = \hat{\gamma}_t^y + \hat{\gamma}_i^f \tag{23}$$

where $\hat{\gamma}$ are the estimated parameters from equation (22).

Future profit expectations tend to be adaptive in nature, simply because a farmer's profit stream is highly correlated with itself over time. The farmer's expectations can be estimated by a weighted average of actual profit (or its prediction when the actual value is missing) over past years, where the coefficients sum to one and decline at a geometric rate (for more on the optimality of this procedure see Just, 1977). The actual estimation was based on only the past three years' profit, because most of the explanatory power is in the profit of the last few years, and because of insufficient data. Mathematically, the estimated expected profit for farmer i at time t is

$$\bar{\tilde{\pi}}_{i,t} = \theta^* \sum_{k=1}^{3} \theta^k \tilde{\pi}_{i,t-k} \qquad where \quad \tilde{\pi}_{i,t} = \begin{cases} \pi_{i,t}, & \text{if } \pi_{i,t} \text{ is available} \\ \hat{\pi}_{i,t}, & \text{if } \pi_{i,t} \text{ is not available} \end{cases} \tag{24}$$

and $\theta^* = 1/\sum_{k=1}^{3} \theta^k$. The estimated expected variance is given by

$$\hat{\Phi}_{i,t} = \theta^* \sum_{k=1}^{3} \theta^k (\pi_{i,t-k} - \bar{\hat{\pi}}_{i,t-k})(\pi_{i,t-k} - \bar{\hat{\pi}}_{i,t-k})'. \tag{25}$$

A simple grid search may be used to identify maximum likelihood estimate of θ.

The endogenous variable L appears on both sides of equation (21), giving a simultaneity problem. To resolve it, we used an instrumental variable approach. The instruments were consistent with the first and second moments of the profit distribution function, that is the means and the components of the variance matrix, in our case 20 variables altogether. Because there is no component of the variance matrix on the right-hand side of equation (21), the equation is identified.[7]

To resolve the simultaneity problem we ran an instrumental logit model. That is,

$$\log \frac{S_k + \delta}{S_1 + \delta} = \alpha + \sum_{j=1}^{J} \beta_j m_j + \sum_{j=1}^{J} \sum_{i>j}^{J} \gamma_{ij} v_{ij} \qquad k = 2...5, \tag{26}$$

where S_k is the share of land allocated to crop k, δ equals $\frac{1}{2 \cdot L}$, m_j is the mean of crop j, and v_{ij} is the covariance of crop i and crop j. We used the minimum chi-square method to estimate this logit model (Maddala, 1983), namely we minimized the weighted sum of square error where the weights were $(\bar{L} S_k S_1)^{\frac{1}{2}}$. Consequently, the resulting estimates are BLUE. Note that equation (26) implicitly assumes that the decision process is a sequential one: in the first step the farmer decides on total amount of land to be cultivated; in the next he decides on the allocation of cultivated land among the five crops. Next, we estimated equation (21) by OLS, replacing the land allocations on the right-hand side by their predicted values obtained from the instrumental logit model.

[7] A built-in routine for simultaneous equations would not have worked in this case because the predicted land allocations have to be positive and sum to one. Furthermore, a built-in routine would have computed predicted values of total profit, instead of land allocations.

The Results

The ratio S_k/S_1 is expected to increase in m_k and decrease in m_1 because the higher the profit of a crop, the greater the amount of land allocated to it. This ratio is also expected to decrease in v_{kk} and increase in v_{11}, because for risk-averse individuals the higher the variance of a crop, the smaller the amount of land allocated to it. Table 1 shows the results of the four instrumental logit regressions. Out of 16 signs, only one has a significantly opposite sign.

Table 2 gives the regression results of equation (21). The first and most important finding is that the elasticity of the measure of absolute risk aversion equals -0.234. This implies decreasing absolute risk aversion on the one hand, and increasing relative risk aversion on the other. The derived behavior of the measure of partial risk aversion is straightforward: it increases with income and decreases with wealth. The results reported in table 2 were obtained for $r = 0.04$ which was the real interest rate during the observed time, and by assigning the marginal propensity to save, b, a value of 0.2. This value was confirmed by the moshav leaders as being realistic. Furthermore, we performed a sensitivity analysis to verify how robust the results were to changes in the marginal propensity to save. Table 3 shows the estimated values of $ln\alpha$ and β for different values of b. For $b = .10$ the estimated values for $ln\alpha$ and β were -11.05 and -0.306, respectively. For $b = .30$ the estimated values for $ln\alpha$ and β were -12.44 and -0.202, respectively. Thus, the estimates for $ln\alpha$ and β appeared to be qualitatively robust to changes in b, i.e. the derived conclusions on the behavior of the measures of risk aversion with respect to wealth or income changes are the same.

It is interesting to compare our results to those of others. A straightforward comparison is possible with Binswanger (1981), whose estimation of the elasticity of the measure of absolute risk aversion with respect to wealth was -.32, this is qualitatively consistent with our finding. A less straightforward comparison is possible with Bardsley and Harris, who reported results for three different zones. Their estimations of the elasticity of the measure of partial risk aversion with respect to income and wealth were in the ranges of 0.129 to 0.194, and -.312 to -.642, respectively. One can easily verify that the following relationships hold: (a) $\epsilon^P_{W_0} = \epsilon^A_W \frac{W_0}{W}$, that is the elasticity of the measure of partial risk aversion with respect to initial wealth equals the elasticity of the measure of absolute risk aversion with respect to wealth multiplied by the share of nonstochastic wealth in total wealth; (b) $\epsilon^P_\pi = \epsilon^A_W \frac{\pi}{W} + 1$, that is the elasticity of the measure of partial risk aversion with respect to the random income equals the elasticity of the measure of absolute risk aversion with respect to wealth times the share of the random income in total wealth plus 1. Thus, our finding that the elasticity of the measure of absolute risk aversion equals -.23 is equivalent to elasticities of the measure of partial risk aversion with respect to initial wealth and random income of -.19 and .95, respectively.[8] Whereas qualitatively Bardsley and Harris' results are consistent with ours, the magnitude of their estimated elasticity of the measure of partial risk aversion with respect to random income appears to be way below ours.

The effect of the characteristics on the implicit cost of labor (shown in table 2) can be divided into to direct and indirect effects. The direct effect is due to the impact of the characteristics on the time required to cultivate one unit of land. The indirect effect comes through the marginal rate of substitution between leisure and money. When less time is devoted to farm activities, more time is devoted to leisure and the marginal rate of substitution goes down. Hence both effects work in the same direction. Diligence, management, motivation and, to a lesser extent, education are expected to have positive coefficients, because they are likely to reduce the time required to cultivate one unit of land. When land quality and labor are substitute factors, the land quality is also expected to have a positive coefficient. Experience has a negative coefficient. One likely explanation

[8] Note that, as reported below, the share of initial wealth in total wealth is 0.8 at the median points.

for this is that experience is associated with older age, and older people work more slowly. Spousal work may increase the time required to cultivate one unit of land, because two people working together are not twice as efficient as one person working alone. Thrift should have a positive coefficient, because thrifty persons tend to waste less time (or to save more time). The cost of labor increases with agricultural knowledge: people who work harder and longer may get higher yields and hence the association with higher agricultural knowledge.

Statistics describing the three coefficients of risk aversion, initial wealth, expected profit, expected wealth, and the implicit costs of labor for the five crops are reported in table 4. The medians of expected and initial wealth are $139,000 and $107,000, respectively, these values are pretty close to reality. The median coefficient of absolute risk aversion is 0.00001. The median coefficient of partial risk aversion is 0.199. The median coefficient of relative risk aversion is 1.05. Antle (1987) estimated the measure of partial risk aversion to be in the range of .19 to 1.77. Binswanger reported similar results: his estimated measure of partial risk aversion lay between .32 and 1.72 for the majority of the individuals. Antle (1989) reconfirmed his 1987 findings by reporting a mean partial risk aversion of 1.11 for one village and 1.14 for the other. We find the measure of partial risk aversion to be in the range of 0.04 to 0.49. Thus, our sample of Israeli farmers exhibits a lower degree of partial risk aversion than that of the Indian farmers. Bardsley and Harris found the measure of partial risk aversion at the median point to be .072, .099, and .696, for the three different zones. Hence in two of the zones, the Australian farmers exhibited lower degrees of partial risk aversion than that of the Israeli farmers, whereas in the third zone the degree of partial risk aversion was similar to that of the Indian farmers. Our estimated measure of relative risk aversion is distributed around 1.05. Even though the mean of the measure of relative risk aversion is statistically different from 1, there is not enough evidence to reject Arrow's hypothesis. Peppers are allotted the highest labor cost, with a median of $1340; next are tomatoes, with a median of $1102; third are onions, with a median of $761; fourth are melons, with a median of $387; and the lowest are eggplants with a median of $316. These results are compatible with reality, where peppers and tomatoes are high-labor crops, and eggplants and melons are low-labor crops.

We found that total wealth is positively correlated with the risk-seeking variable constructed by the Delphi panel (with a correlation coefficient of 0.41). The main criterion guiding the Delphi panel members in evaluating the risk-seeking attribute was the farmer willingness to adopt new technology such as a new variety, pesticide, fertilizer, etc. The positive correlation means that the richer the farmer, the less risk-averse he is, hence this finding is consistent with the evidence for decreasing absolute risk aversion presented above. It is not clear, however, to what extent richer farmers are less conservative or, nonconservative farmers are richer.

Summary and Conclusions

We developed a methodology to assess the effect of wealth changes on the measures of absolute, relative, and partial risk aversion. The behavior of all three measures were shown to be determined by a single parameter, the elasticity of absolute risk aversion with respect to wealth. Our main findings were that the measure of absolute risk aversion decreases with wealth, the measure of relative risk aversion increases with wealth, and the measure of partial risk aversion increases in risky income and decreases with nonstochastic initial wealth. These findings suggest empirical evidence supporting Arrow's hypotheses.

Table 1. Parameter Estimates

Dependent Variable	Independent Variable	Estimated Parameter	T Ratio	P Value
S_2/S_1	m_1	-1.2e-5	-3.26	0.0013
	m_2	6.6e-6	2.59	0.0102
	v_{11}	2.0e-8	0.591	0.5552
	v_{22}	1.0e-7	3.63	0.0004
S_3/S_1	m_1	-1.9e-6	-0.343	0.7317
	m_3	-2.7e-6	-0.483	0.6295
	v_{11}	2.8e-8	0.545	0.5867
	v_{33}	2.4e-8	0.221	0.8253
S_4/S_1	m_1	-1.0e-5	-1.869	0.0633
	m_4	-2.5e-6	-0.310	0.7571
	v_{11}	-5.9e-8	-1.177	0.2408
	v_{44}	6.5e-8	0.332	0.7406
S_5/S_1	m_1	-3.5e-6	-0.722	0.4712
	m_5	5.4e-6	1.129	0.2603
	v_{11}	-2.3e-8	-0.518	0.6053
	v_{55}	-2.9e-7	-2.088	0.0383

Table 2. Parameter Estimates

Variable	Estimated Parameter	T Ratio	P Value
Intercept ($ln\alpha$)	-12.0	-5.59	0.0001
Elasticity of ARA (β)	-0.234	-1.68	0.0924
Diligence	0.006	1.24	0.2156
Thrift	0.028	5.18	0.0001
Management	0.010	1.60	0.1098
Experience	-0.145	-2.22	0.0268
Spouse work	-0.152	-4.08	0.0001
Agricultural knowledge	-0.264	-4.29	0.0001
Motivation	0.012	2.13	0.0339
Land quality	0.009	1.63	0.1044
Education	0.002	0.86	0.3904

R-Square 0.99
Number of Observations 777

Table 3. Sensitivity Analysis

b	0.10	0.15	0.20	0.25	0.30
$ln\alpha$	-11.05	-11.64	-12.02	-12.27	-12.44
β	-0.306	-0.262	-0.234	-0.210	-0.202

Table 4. Descriptive Statistics

Variable	Median	Mean	Standard Error
Absolute risk aversion	1.0E-5	1.0E-5	4.0E-8
Partial risk aversion	0.199	0.206	0.0043
Relative risk aversion	1.05	1.04	.016
Initial wealth	1.07E5	1.09E5	2.4E3
Expected profit	2.67E4	2.73E4	5.92E2
Total wealth	1.39E5	1.41E5	2.84E3
Cost of labor:			
peppers	1340	1396	24.4
tomatoes	1102	1154	28.6
onions	761	762	16.8
melons	387	417	12.7
eggplants	316	411	22.1

References

Antle, J. M. "Econometric Estimation of Producers' Risk Attitudes." *American Journal of Agricultural Economics.* 69(1987):509-22.

Antle, J. M. "Nonstructural Risk Attitude Estimation." *American Journal of Agricultural Economics.* 71(1989):774-84.

Arrow, K. J. *Essays in the Theory of Risk-Bearing.* Chicago, Ill.: Markham Publishing Co., 1971.

Bardsley, P. and M. Harris. "An Approach to the Econometric Estimation of Attitudes to Risk in Agriculture." *The Australian Journal of Agricultural Economics.* 31(1987):112-26.

Bar-Shira, Z. "An Approach to the Econometric Estimation of Attitudes to Risk in Agriculture: Comment." *The Australian Journal of Agricultural Economics.* 35(1991):315-8.

Bar-Shira, Z. "Nonparametric Test of the Expected Utility Hypothesis." *The American Journal of Agricultural Economics.* 74(1992):523-33.

Binswanger, H. P. "Attitude Toward Risk: Experimental Measurement in Rural India." *American Journal of Agricultural Economics.* 62(1980):395-407.

Binswanger, H. P. "Attitude Toward Risk: Theoretical Implication of an Experiment in Rural India." *Economic Journal.* 91(1981):867-90.

Binswanger, H. P. "Empirical Estimation and Use of Risk Preferences: Discussion." *American Journal of Agricultural Economics.* 64(1982):391-3.

Buschena, D. E. and D. Zilberman. "The Effects of Alternative Similarity on Risky Choice: Implications for Violations of Expected Utility." U. C. Berkeley, working paper, 1992.

Dillon, J. L. and P. L. Scandizzp. "Risk Attitudes of Subsistence Farmers in Northeast Brazil: A Sampling Approach." *American Journal of Agricultural Economics.* 60(1978):425-34.

Hazell, P. B. R. "Application of Risk Preference Estimates in Firm- Household and Agricultural Sector Models." *American Journal of Agricultural Economics.* 64(1982):384-90.

Just, R. E. "Estimation of Adaptive Expectation Model." *International Economic Review.* 18(1977):629-44.

Just, R. E. and D. Zilberman. "Stochastic Structure, Farm Size and Technology Adoption in Developing Agriculture." *Oxford Economic Papers.* 35(1983):307-28.

Just, R. E., E. Hochman, D. Zilberman and Z. Bar-Shira. "Alternative Approaches for Allocating Observed Input Use Among Crops." *American Journal of Agricultural Economics.* 72(1990):200-09.

Kahneman, D. and A. Tversky. "Prospect Theory: An Analysis of Decisions Under Risk." *Econometrica.* 47(1979):263-91.

Laffont, J. J. *Economics of Uncertainty and Information.* Cambridge, MA: MIT Press, 1989. Translated by John P. Bonin and Helene Bonin.

Love, H. A. and S. T. Buccola. "Joint Risk Preference-Technology Estimation with a Primal System." *American Journal of Agricultural Economics.* 73(1991):765-74.

Maddala, G. S. *Limited Dependent and Qualitative Variables in Economics.* Cambridge, MA: Cambridge University Press, 1983.

Machina, M. J. "Choice Under Uncertainty: Problem Solved and Unsolved." *Economic Perspectives.* 1(1987):121-54.

Menezes, F. C. and L. D. Hanson. "On the Theory of Risk Aversion." *International Economic Review.* 11(1970):181-7.

Moscardi, E. and A. de Janvry. "Attitudes Toward Risk Among Peasants: An Econometric Approach." *American Journal of Agricultural Economics.* 59(1977):710-6.

Newbery, D. M. G. and J. E. Stiglitz. *The Theory of Commodity Price Stabilization.* Oxford: Clarendon Press, 1981.

Pope, R. D. "Empirical Estimation and Use of Risk Preferences: An Appraisal of Estimation Methods That Use Actual Economic Decision." *American Journal of Agricultural Economics.* 64(1982):376-83.

Pope, R. D. and R. E. Just. "On Testing the Structure of Risk Preferences in Agricultural Supply Analysis." *American Journal of Agricultural Economics.* 73(1991):743-8.

Pratt, J. W. "Risk Aversion in the Small and in the Large." *Econometrica.* 32(1964):122-36.

Quizon, J. B., H. P. Binswanger and M. J. Machina. "Attitude Toward Risk: Further Remarks." *Economic Journal.* 94(1984):144-8.

Robison, L. J. "An Appraisal of Expected Utility Tests Constructed from Responses to Hypothetical Questions and Experimental Choices." *American Journal of Agricultural Economics.* 64(1982):367-75.

Rubinstein, A. "Similarity and Decision-Making Under Risk (Is There Utility Resolution to the Allais Paradox?)." *Journal of Economic Theory.* 46(1988):145-53.

Sandmo, A. "On the Theory of the Competitive Firm Under Price Uncertainty." *American Economic Review.* 61(1971):65-73.

Zeckhauser, R. and E. Keeler. "Another Type of Risk Aversion." *Econometrica.* 38(1970): 661-5.

Zusman, P. *Individual Behavior and Social Choice in a Cooperative Settlement.* Jerusalem, Israel: The Magnes Press, ,1988.