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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. © 1997 Elsevier Science B.V.

1. 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, 1971; Just and Zilberman, 1983). In particular, specific assumptions regarding the signs, magnitudes, and behaviors with respect to wealth changes of the measures are required. Commonly, theoretical studies assume positive measures of risk aversion and adopt Arrow's hypotheses on the effect of wealth on the measures of risk aversion i.e., decreasing absolute and increasing relative risk aversion.

While there exists some empirical evidence on the signs and magnitudes of these measures there is a little empirical evidence on the effect of wealth changes on them. Thus, the objective of this study is two-fold: (i) estimating the orders of magnitudes of the measures of risk aversion; (ii) estimating the effects of wealth changes on the measures, thereby testing Arrow's conjectures about their behavior with respect to income or wealth. It is worthwhile to note that such empirical results are of special importance to the agricultural sector. Agricultural production is characterized by considerable risk and significant governmental intervention and thus aggregate measures of risk aversion and their properties with respect to wealth have very important policy implications.

The literature has attempted to provide empirical evidence of individuals' risk attitudes. These attempts may be classified into two main approaches: experimental and econometric. A critical difference between them is that the former is based on simulations in which individuals are presented with hypothetical questionnaires regarding risky alternatives, with or without real payments, while the latter has the advantage of being based on individuals' actual decisions. The experimental approach, for example, has been used by Dillon and Scandizzo (1978) to

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elicit risk attitudes of subsistence farmers in northeast Brazil, and by Binswanger (1980), Binswanger (1981) and Quizon et al. (1984) to analyze a fairly large-scale experiment, with real significant payments, in rural India.

The econometric approach has been used in variety of circumstances. Moscardi and de Janvry (1977), and Shahabuddin et al. (1986) used such an approach in which the decision-makers were assumed to follow a safety-first rule. Antle (1987, 1989), Bardsley and Harris (1987), Love and Buccola (1991), Pope and Just (1991), and Saha et al. (1994) used econometric approaches to study of risk attitudes of decision-makers assuming expected utility maximization. Newbery and Stiglitz (1981), Robison (1982), Pope (1982), Hazell (1982) and Binswanger (1982) present a comprehensive discussion of the relevant literature.

The papers by Pope and Just, Bardsley and Harris, and Saha are the closest to this one. Pope and Just developed tests for distinguishing between constant absolute, relative, and partial risk aversion. In contrast, they did not consider an elasticity of risk aversion and thus did not estimate a systematic way in which risk aversion differs among individuals. Hence, the specific hypotheses of Pope and Just are special cases of the general model of this paper. In Section 6 we compare our results to others including Bardsley and Harris, and Saha.

A large body of evidence against the expected utility hypothesis has been accumulating over past decades (i.e., Kahneman and Tversky, 1979; 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 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) indicates that the expected utility hypothesis is likely to be violated when alternatives are similar in the sense that either prizes or probabilities are indistinguishable among the alternatives. Buschena and Zilberman (1992) showed that the expected utility hypothesis is less likely to hold when comparing alternative pairs that are highly dissimilar in both magnitude and probability. [1] However, real-life alternatives appear to be relatively similar, but distinguishable. Thus the expected utility hypothesis is apparently valid for the purpose of this paper.

This paper proceeds as follows. Section 1 reviews the relevant literature. Section 2 discusses the relationships between the absolute, relative and partial measures of risk aversion, and theoretical responses to changes in income or wealth under each. Section 3 outlines the model and derives some conclusions on the effect of risk on production. Section 4 gives empirical background and describes the data. In Section 5, the estimation procedure is outlined. Section 6 presents the results and compares them to results which have been obtained in other studies. Then conclusions are presented.

2. 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 non-stochastic part—initial wealth. Arrow pointed out that intuition implies that an 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.

In situations where both the stochastic and non-stochastic components of the wealth are changing proportionally, the appropriate measure is 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

[1] Both prizes and probabilities of the lotteries in one pair are significantly different from those of the lotteries in the other pair.

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. 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 be equal to one for some wealth between zero and infinity.

A third measure of risk aversion is the measure of partial risk aversion (Menezes and Hanson, 1970; Zeckhauser and Keeler, 1970),

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

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 variable.

The behavior of the measure of partial risk aversion under wealth changes or risky income changes can be 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 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. 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 $\epsilon_A^W > -1$, 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 $0 > \epsilon_A^W > -1$ is equivalent to decreasing absolute risk aversion and increasing relative risk aversion. Note, that $\epsilon_A^W = -1$ is equivalent to $R' = A'W + A = 0$, or in words, constant relative risk aversion. 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.

3. Methodology

The model presented below describes the following farming situation on an Israeli Moshav: I small farm owners, who form a village, allocate a fixed amounts 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 exhibit constant returns to scale

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

[3] To see this, denote relative risk as $\bar{R}$, and then integrate twice the expression $U''/U' > -\bar{R}W$.

with fixed proportions production. The constant-returns-to-scale assumption is regarded as relatively innocuous for this paper due to the fact that the total farm scale is constant in the sample with regard to both time and land. 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 achieved without the loss of efficiency usually caused by increasing all inputs except the managerial input. The technology assumption is further justified by Just et al. (1990).

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. In this study the absence of a labor market is due to the fact that farmers obey the principle of *self-employment*. [4] 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 an asset portfolio. Each farmer is assumed to act as an expected utility maximizer, and his decision problem can be written as

$$\max_{L,T^l} E\left[U(W,T^l)\right] = \max_{L,T^l} E\left[U\left(W_0 + \pi' L, T^l\right)\right] \tag{9}$$

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 amounts allocated to J crops, π is a corresponding vector of net returns, 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 (Eq. (9.a)) is the time constraint reflecting that the total amount of available time minus time spent on farm activities is equal to time devoted to leisure. The second constraint (Eq. (9.b)) is the capacity constraint indicating that total cultivated land can not exceed the total amount of available land. [5]

Substituting the time constraint (Eq. (9.a)) into the objective function (Eq. (9)) and assuming that the capacity constraint (Eq. (9.b)) is not binding, [6] the first-order conditions are

$$\frac{\partial E[U]}{\partial L} = E[\pi \cdot U_W] - E[T \cdot U_{T^l}] = 0 \tag{10}$$

where U_W and U_{Tl} are the partial derivatives with respect to wealth and leisure, 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 $(\bar{\pi}_j/T_j) \cdot U_W > U_{T^l}$ for a risk-averse individual ($A > 0$). 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

[4] The self-employment principle is one of the five principles which define a Moshav, which is an agricultural settlement in Israel (for more details see Zusman (1988)).

[5] Note that this decision problem is static in nature. Generalizing this framework following the dynamic model of agricultural decision making under risk of Hertzler (1991) would also be desirable but is beyond the scope of this paper.

[6] Note that in this study, observed land allocations sum to less than total land available on the farm.

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 has led researchers to model the choice of crop portfolio in the same framework as choice of an asset portfolio. Generally, the approach 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 straightforward hypotheses testing.

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

$$\begin{aligned} U_W &= \overline{U}_W + \overline{U}_{W,W}(\pi - \overline{\pi})'L \\ &= \overline{U}_W \left[1 + \frac{\overline{U}_{W,W}}{\overline{U}_W}(\pi - \overline{\pi})'L \right] \end{aligned} \tag{11}$$

where $\overline{U}_W$ and $\overline{U}_{W,W}$ are U_W and $U_{W,W}$ evaluated at $\overline{W}$, respectively. Substituting Eq. (11) into Eq. (10) and dividing by $\overline{U}_W$ gives

$$\begin{aligned} &\overline{\pi} - T\frac{\overline{U}_{T^l}}{\overline{U}_W} + \frac{\overline{U}_{W,W}}{\overline{U}_W} E[\pi(\pi - \overline{\pi})']L \\ &= \overline{\pi} - T\frac{\overline{U}_{T^l}}{\overline{U}_W} + \frac{\overline{U}_{W,W}}{\overline{U}_W} \Phi L = 0 \end{aligned} \tag{12}$$

where Φ is the covariance matrix of net profits from the various crops. The term $T\frac{\overline{U}_{T^l}}{\overline{U}_W}$ represents the implicit cost of labor per unit of land. [7] 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 parallel 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

$$A \equiv -\frac{\overline{U}_{W,W}}{\overline{U}_W} = A(\overline{W}). \tag{13}$$

The functional form, $A = \alpha \overline{W}^{\beta}$, is sufficiently flexible to accommodate either risk-seeking or risk-averse behavior-α greater than (smaller than) zero implies risk aversion (risk seeking). Further, it does not restrict the sign of the elasticity of absolute risk aversion with respect to W, given by

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

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

$$\overline{\pi} - T\frac{\overline{U}_{T^l}}{\overline{U}_W} - \alpha \overline{W}^{\beta} \Phi L = 0, \tag{15}$$

which, after some algebraic manipulations, can be written as

$$\Phi L = \frac{1}{\alpha} \overline{W}^{-\beta} \left(\overline{\pi} - T\frac{\overline{U}_{T^l}}{\overline{U}_W} \right). \tag{16}$$

Since L is observed directly and Φ and $\overline{\pi}$ bar can be estimated from the available data, this relationship is estimable if $\overline{W}$ and $T\overline{U}_{T^l}/\overline{U}_W$ are directly observable. To attain estimability, one needs estimates for W_0 and T. Under the permanent income hypothesis of Friedman, the individuals' consumption and hence saving is proportional to permanent income. As a consequence, the initial wealth at each time point is the sum of all past discounted expected profits multiplied by the marginal propensity to save. Formally

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

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

[7] Note that the units of $T\frac{\overline{U}_{T^l}}{\overline{U}_W}$ are $\frac{\text{time}}{\text{land}}\frac{\text{utility}}{\text{time}} / \frac{\textit{funcyutility}}{\text{money}} = \frac{\text{money}}{\text{land}}$.

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

$$\bar{\pi} - T\frac{\bar{U}_{T^l}}{\bar{U}_W} = \bar{\pi}^{\mu}, \quad (18)$$

where μ is the elasticity of net benefit with respect to profit. Now let μ vary with the farmer's personal and technological characteristics such as management ability, land quality, etc. That is: $\mu = \Sigma\psi_i c_i$, where c_i is the ith characteristic and ψ_i is the corresponding coefficient. Note that the farmer's characteristics reflect differences in the farmer's ability (i.e., the time required to cultivate one unit of land). Replacing μ with the linear combination of characteristics, Eq. (18) becomes:

$$T\frac{\bar{U}_{T^l}}{\bar{U}_W} = \bar{\pi} - \bar{\pi}(\Sigma\psi_i c_i). \quad (19)$$

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

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

Taking the natural logarithm of both sides yields

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

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

4. Empirical background and data

The methodology presented in the previous section is used in this section to estimate the risk attitudes of individual farmers of the same age group 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 sparsely 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 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 attitude. 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, eggplant, and melons. Almost all farmers grow tomatoes, bell peppers and melons. A smaller number also grow eggplant 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., 1990), 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.

5. 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 assumed to be based on previous years' profits. Since no farmer grows every crop every year some values are missing. A farmer who has such missing values is assumed to form perceptions of profit for those years based on farms which are similar to his/her own in terms of size, location, and owner wealth. These missing values are estimated 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 the $\hat{\gamma}$ are the estimated parameters from Eq. (22).

Future profit expectations in an environment which is Markovian up to white noise tend to be adaptive in nature (see Just, 1977).[8] Thus, 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). Following Berhman (1968), the actual estimation was based on only the past 3 years' profit, because most of the explanatory power is in the profit of the last few years, and because of insufficient data. Adapting Just (1974), the estimated expected profit for farmer i at time t is

$$\bar{\bar{\pi}}_{i,t} = \theta^* \sum_{k=1}^{3} \theta^k \tilde{\pi}_{i,t-k} \tag{24}$$

[8] There are exceptions. For example, see Boussard (1982) who shows how risk expectations can generate chaotic motion.

where

$$\tilde{\pi}_{i,t} = \begin{cases} \pi_{i,t}, \text{ if } \pi_{i,t} \text{ is available} \\ \hat{\pi}_{i,t}, \text{ if } \pi_{i,t} \text{ is not available} \end{cases} \tag{25}$$

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

$$\hat{\Phi}_{i,t} = \theta^* \sum_{k=1}^{3} \theta^k \times \left(\pi_{i,t-k} - \bar{\bar{\pi}}_{i,t-k}\right) \times \left(\pi_{i,t-k} - \bar{\bar{\pi}}_{i,t-k}\right)'. \tag{26}$$

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

The endogenous variable L appears on both sides of Eq. (21), implying a simultaneity problem. To resolve it, we used a two-stage instrumental variable approach. The instruments were the first and second moments of the profit distribution function, i.e., the means and the components of the variance matrix (20 variables). Because there is no component of the variance matrix on the right-hand side of Eq. (21), the equation is identified.

The first stage involves an instrumental logit model. That is,

$$\log\frac{S_k + \delta}{S_1 + \delta} = \alpha + \sum_{j=1}^{J} \beta_j m_j + \sum_{j=1}^{J} \sum_{i>j}^{J} \gamma_{ij} v_{ij} \quad k=2\ldots5, \tag{27}$$

where S_k is the share of land allocated to crop k, $\delta = \frac{1}{2 \cdot \bar{L}}$, 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). Specifically, we minimized the weighted sum of squared errors where the weights were $(\bar{L}S_k S_1)^{\frac{1}{2}}$. Consequently, the resulting estimates are best linear unbiased estimates. Note that Eq. (27) 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. The second stage involves replacing the land allocations on the right-hand side of Eq. (21) by their predicted values obtained from the instrumental logit model.

Finally, before proceeding to estimation, we consider possible variation in risk attitude cross individuals. Following previous studies (Dillon and Scandizzo, 1978; Moscardi and de Janvry, 1977; Binswanger, 1980, 1981, 1982; Shahabuddin et al., 1986) concerning elicitation of risk attitudes, we related variation in risk attitude to variation in socioeconomic characteristics among individuals. Specifically, we replace the parameter α in Eq. (21) by a linear combination of the characteristics. This allows magnitudes of the measures of risk aversion to vary across individuals but keeps the elasticity of absolute risk aversion, β, constant. Thus the estimated value for β should be interpreted as an estimate of aggregate elasticity. The extent to which the hypothesis of constant elasticity is credible depends on the empirical background.

6. 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 significant opposite sign.

Table 1
Parameter estimates of Eq. (27)

Dependent variable	Independent variable	Estimated parameter	T ratio	P value
S_2/S_1	m_1	−1.2e−5	−3.60	0.0004
	m_2	5.5e−6	2.23	0.0265
	v_{11}	1.1e−8	0.34	0.7350
	v_{22}	8.5e−8	3.24	0.0014
S_3/S_1	m_1	−3.0e−6	−0.59	0.5536
	m_3	−1.0e−6	−0.19	0.8503
	v_{11}	6.5e−8	1.33	0.1854
	v_{33}	−1.0e−9	−0.01	0.9922
S_4/S_1	m_1	−1.1e−5	−2.31	0.0218
	m_4	−4.4e−6	−0.59	0.5557
	v_{11}	−3.6e−8	−0.75	0.4519
	v_{44}	−2.8e−9	−0.02	0.9873
S_5/S_1	m_1	−3.9e−6	−0.88	0.3786
	m_5	5.9e−6	1.13	0.2075
	v_{11}	−1.4e−8	−0.33	0.7399
	v_{55}	−2.8e−7	−2.12	0.0354

Table 2
Parameter estimates of Eq. (21)

Variable	Estimated parameter	T ratio	P value
Elasticity of ARA (β)	−0.316	−2.638	0.0001
Ln α (average)	−11.256	−6.077	0.0001
$\partial \ln \alpha / \partial$Diligence	1.853	3.141	0.0017
Thrift	0.854	1.491	0.1364
Management	−2.040	−2.786	0.0055
Experience	−1.972	−2.614	0.0091
Spouse work	0.361	0.771	0.4411
Agric. knowledge	0.991	1.417	0.1569
Motivation	0.311	0.499	0.6179
Land quality	0.234	0.353	0.7243
Education	1.267	5.945	0.0001
$\partial \mu / \partial$Diligence	0.177	3.137	0.0018
Thrift	0.094	1.720	0.0857
Management	−0.189	−2.698	0.0071
Experience	−0.174	−2.416	0.0159
Spouse work	0.024	0.552	0.5809
Agric. knowledge	0.085	1.268	0.2051
Motivation	0.021	0.353	0.7243
Land quality	0.015	0.231	0.8187
Education	0.115	5.765	0.0001

R-square = 0.99. Number of observations = 826.

Table 2 gives the regression results of Eq. (21). The first and most important finding is that the elasticity of the measure of absolute risk aversion is −0.316. The associated T-ratio shows that it is significantly different from zero as well as from 1. Thus we accept the hypotheses of decreasing absolute risk aversion and increasing relative risk aversion over the simple alternative of constant absolute risk aversion or constant relative risk aversion. 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 $b = 0.10$ the estimated values for $\ln \alpha$ and β were −10.51 and −0.37, respectively. For $b = 0.30$ the estimated values for $\ln \alpha$ and β were −11.62 and −0.29, respectively.

Table 3
Sensitivity analysis with respect to the marginal propensity to save

b	0.10	0.15	0.20	0.25	0.30
$\ln \alpha$	−10.51	−10.95	−11.25	−11.46	−11.62
β	−0.37	−0.34	−0.31	−0.29	−0.29

Thus, the estimates for $\ln \alpha$ and β appear to be robust to changes in b, i.e., the derived qualitative 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 −0.32. This is strikingly close to 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 −0.312 to −0.642, respectively. One can easily verify that the following relationships hold: (a) $\epsilon^P_{W_o} = \epsilon^A_W \frac{W_o}{W}$, that is, the elasticity of the measure of partial risk aversion with respect to initial wealth is equal to 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 is equal to 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 is equal to −0.316 is equivalent to elasticities of the measure of partial risk aversion with respect to initial wealth and random income of −0.19 and 0.95, respectively. [9] Whereas Bardsley and Harris' results are consistent with ours qualitatively, the magnitude of their estimated elasticity of the measure of partial risk aversion with respect to random income appears to be much lower than ours.

The estimated effects of farmer characteristics on risk aversion are detailed in the central part of Table 2. The most significant characteristics are diligence, management, experience and education. Notably, farmers with a higher level of experience as well as farmers with better managerial abilities exhibit a lower degree of risk aversion. The intuition is simple. Risk is a complicating factor which farmers with less experience or less managerial ability try to avoid. Higher levels of education are associated with higher risk aversion, suggesting that educated farmers understand better how to avoid risk. Diligence is also associated with higher risk aversion. A possible explanation might be that farmers who work harder can reduce ex-post risk and thus appear risk-averse ex-ante.

The effects of farmer characteristics on the implicit cost of labor (bottom part of Table 2) can be divided into 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 so the marginal rate of substitution goes down. Hence both effects work in the same direction. Diligence, agricultural knowledge 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. Thrift should have a positive coefficient because thrifty persons tend to waste less time (or to save more time). When land quality and labor are substitute factors, the land quality is also expected to have a positive coefficient. The cost of labor may increase with management and experience: people who work harder and longer may get higher yields and hence be characterized as having higher management ability and experience.

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. A complete illustration of the distributions of initial wealth, the measure of partial risk aversion, and the implicit cost of labor is given by their estimated empirical densities, depicted

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

Table 4
Estimated descriptive statistics of risk aversion and farm financial characteristics

Variable	Median	Mean	Standard Error
Absolute risk aversion	4.4e-6	4.5e-6	3.2e-8
Partial risk aversion	0.117	0.122	0.0025
Relative risk aversion	0.615	0.611	0.0086
Initial wealth	1.07e5	1.09e5	2.40e3
Expected profit	2.67e4	2.73e4	5.92e2
Total wealth	1.39e5	1.41e5	2.84e3
Cost of labor:			
Peppers	1172	473	176
Tomatoes	929	324	173
Onions	649	306	83
Melons	303	178	54
Eggplants	236	200	49

in Figs. 1–3, respectively. The medians of expected and initial wealth are US$139,000 and US$107,000, respectively. These values are close to reality. The median coefficient of absolute risk aversion is 0.0000044. The median coefficient of relative risk aversion is 0.615. The median coefficient of partial risk aversion is 0.117. For comparison, Saha et al. (1994) estimated the measure of relative risk aversion for Kansas wheat farmers to be 5.4 and Antle (1987) estimated the measure of partial risk aversion of Indian farmers to be in the range of 0.19 to 1.77. Binswanger reported similar results: his estimated measure of partial risk aversion was between 0.32 and 1.72 for the majority of the individuals. Antle (1989) re-confirmed 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 0.52. Thus, our sample of Israeli farmers exhibits a lower degree of partial risk aversion than that of Indian farmers.

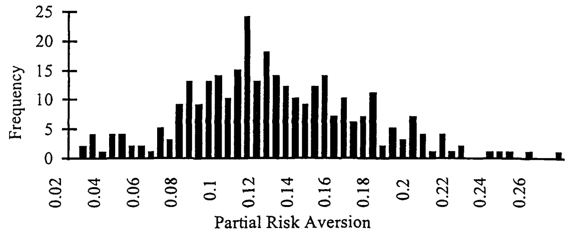

Fig. 2. The partial risk aversion distribution.

Bardsley and Harris found the measure of partial risk aversion at the median point to be 0.072, 0.099, and 0.696, for their three different zones of Australia. Hence, in two of the zones, Australian farmers exhibited lower degrees of partial risk aversion than 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 has a median value of 0.615. Peppers are allotted the highest labor cost, with a median of US$1172 followed by tomatoes with a median of US$929, onions with a median of US$649, melons with a median of US$303, and eggplant with a median of US$236. These results are compatible with reality, where peppers and tomatoes are high-labor crops, and eggplant and melons are low-labor crops.

To confirm our results, we note that total wealth is positively correlated with the risk-seeking attitude variable constructed by the Delphi panel (with a correlation coefficient of 0.46). 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. This positive correlation means that the richer the farmer, the less risk-averse he is.

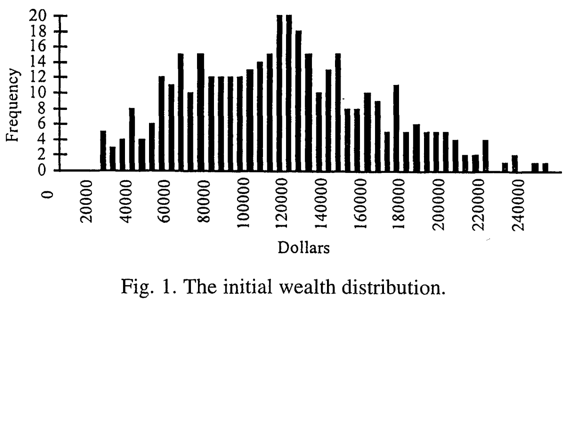

Fig. 1. The initial wealth distribution.

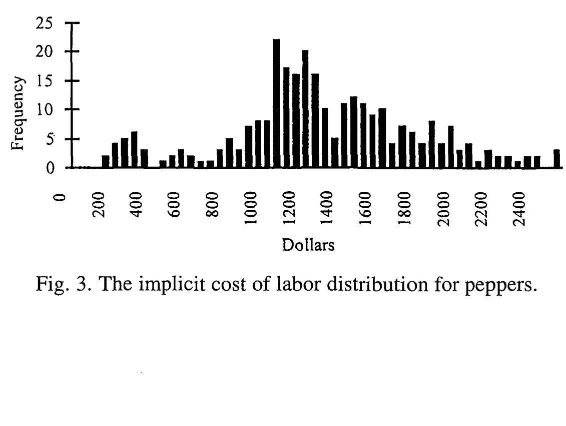

Fig. 3. The implicit cost of labor distribution for peppers.

Hence this finding is consistent with the evidence of decreasing absolute risk aversion presented above.

7. Summary and conclusions

This paper develops 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. Regarding Israeli farmers, 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 non-stochastic initial wealth. These findings suggest empirical evidence supporting Arrow's hypotheses. [10]

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[10] Note that using the results obtained in this study for predicting choices in different circumstances should be done with care.

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