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Risk and Seasonality in an Empirical Model of the Farm Household*

Emmanuel Skoufias**

This paper develops and tests a dynamic/stochastic model of labor demand and supply of farm households in a developing country. Seasonality in agriculture is modeled as a dynamic two stage process (planting and harvesting) with sequential dependence of decisions. Yield uncertainty is an important determinant of behavior in the planting stage only. It is demonstrated that the introduction of risk results in nonseparability in the planting stage, since the consumption and leisure choices of the household affect its input decisions for on-farm production. The proposed model is estimated using household panel data from India. The empirical results suggest significant intertemporal substitution in the labor supply of females although no such evidence is found for males. Consistent estimates of the male and female labor demand functions in the planting and harvesting are derived by fixed effect econometric methods that control for the nonseparability of the model.

I. Introduction

Farming and wages from farm-related work are the major sources of income for many households in rural areas of developing countries. Seasonal fluctuations in wages and employment opportunities, in combination with the uncertainty about weather conditions and future profits from farming may thus have serious effects on household income and welfare (Chambers, 1982; Sahn, 1990). Although the recent literature on agricultural households has provided many valuable insights on

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[**] Professor, the Economic Institute, Department of Economics, and Institute of Behavioral Science, University of Colorado at Boulder, U.S.A.

rural household behavior (e.g. Singh, et al., 1986), there has been little emphasis on the sources of interseasonal variations in earnings and employment in rural economies. Most empirical studies to date have relied on a static framework that abstracts from the seasonal nature of agriculture production decisions and ignores the consequences of risk.

This paper extends the basic model of the farm household by introducing risk and seasonality in an empirically useful way. The model developed relies on the λ-constant framework used in analyses of labor supply over the life-cycle (Heckman and Macurdy, 1980; MaCurdy 1981, 1985). Two types of labor are distinguished based on gender in order to account for the heterogeneity of male and female labor in both production and consumption. Labor supply at any given period (season) is determined by the current wage and the marginal utility of wealth that summarizes the influence of all past events, and expectations about future events, on current decisions. The seasonal nature of agriculture is captured by specifying each crop-cycle as consisting of two stages, planting and harvesting. Farmers are modeled as making their input decisions sequentially while recognizing that their decisions today will have an effect on their input decisions tomorrow. It is demonstrated that in the planting stage the labor used on the farm is dependent on (nonseparable from) the consumption and labor supply choices of the household as in Roe and Graham-Tomasi (1986). The conditions for separate estimation of the input decision rules from the consumption and leisure decisions of the household are explored. While the methodology proposed does not provide a direct test of nonseparability it is argued that fixed-effect methods will eliminate the bias arising from nonseparability.[1]

The key parameters estimated from the model include the elasticity of substitution of labor supply for both males and females across seasons, and the elasticity of labor demand for male and female labor used on the farm in the planting and the harvesting stage of the agricultural cycle. Such elasticities play a crucial role in anlayzing the employment and wage effects of technological improvements and production practices aimed at increasing agricultural output and utilizing labor more evenly across seasons.

The paper is organized as follows: Section 2 outlines a dynamic agricultural household model with uncertainty and discusses the issues arising in this dynamic context. Section 3 contains the description of the

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[1] Explicit tests of nonseparability are provided by Lopez (1984), Pitt and Rosenzweig (1986) and Benjamin (1992).

data, the econometric specification and the empirical results. Section 4 concludes.

II. Theoretical Model

It is assumed that spot markets for labor and the homogeneous agricultural commodity are competitive. Family and hired labor are perfect substitutes in the production process and household members are indifferent between working on or off the farm. Male and female labor, however, are treated as heterogeneous inputs. Each member's endowment of time in each period can be divided between leisure and work. Wealth is transferred from period to period by holding an asset with a fixed and known real rate of return.[2] Wealth at the end of the lifetime is assumed to be equal to zero (or given exogenously) which amounts to the restriction that at the end of the lifetime all outstanding loans are repaid.

Households maximize discounted expected lifetime utility subject to their budget and asset accumulation constraint. The life time preference function of a household is assumed to be strongly separable over time and satisfying the typical concavity assumptions, with utility at time t given by:

$$U(t)=U[C(t), M(t), F(t), X(t)] \tag{1}$$

where C(t) is consumption of the Hicksian composite commodity in period t, M(t) and F(t) is hours of leisure of male and female members, respectively, and X(t) summarizes observable and unobservable factors affecting tastes.

On the production side, households produce an agricultural commodity every crop-cycle, with the use of family and hired male and female labor, land, bullocks and other forms of capital. To capture the seasonality and sequential nature of agricultural production, each crop-cycle is assumed to last two periods (stages). In stage 1 (t an odd number) production inputs are chosen and the crop is planted and grown. The choice of inputs in this first stage is based on expected output conditional on the information at that stage, since random events such as weather changes and pests may occur during plant growth. The output of the first stage which is observed by the farmer (but not the

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[2] The theoretical model could also be extended to the case of imperfect credit markets in a manner similar to Altonji and Siow (1987).

econometrician) in the beginning of the second stage, is the standing crop. In the second stage (t an even number) all uncertainty concerning production are resolved and the standing crop is harvested using labor. In principle farmers are also subject to output and input price risks. In this paper, output variation (yield risk) is treated as the main source of risk within each crop cycle. The above may be summarized by the following notation:

$$Q(t)=\Gamma_t[m(t),\ f(t),\ K(t),\ \epsilon(t+1)],\ (t=\text{odd}), \tag{2a}$$

$$Q(t)=\Gamma_t[m(t),\ f(t),\ Q(t-1)],\ (t=\text{even}), \tag{2b}$$

where $Q(t)$ is agricultural output in period t, $\Gamma_t(.)$ summarizes the production function in period (stage) t, $m(t)$ and $f(t)$ are total (family and hired) male and female labor in period t, $K(t)$ is a vector of quantities of other inputs, (assumed fixed) such as land, $\epsilon(t+1)$ is the stochastic disturbance to the production technology due to weather variability, pests, drought, etc., distributed independently across farmers and over time.

More explicitly, in the planting stage ($t=\text{odd}$) farmers are assumed to know the wages that will prevail in the market within the current crop-cycle as well as the distribution of the disturbance term in the production function.[3] Production costs incurred for the inputs utilized (fertilizer, labor, etc.) are assumed to be paid in this stage. In addition, farmers know that their input decisions this stage will affect their input decisions next stage (sequential dependence) and they know the exact functional form of this interdependence (Antle, 1983).

At the beginning of the harvesting stage ($t=\text{even}$), $\epsilon(t)$ is realized and farmers observe the standing crop $[Q(t-1)]$. In this stage profits are realized also. Notice that the wage rates of the next crop-cycle do not

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[3] The assumption that farmers know the wage rates of the harvesting stage in a given crop-cycle is made so as to facilitate the analysis on the labor demand side; in this setting, in the planting stage farmers face only one source of risk, yield risk ($\epsilon(t+1)$). Note, however, that no assumption is made with respect to the wage rates in future crop cycles. The assumption of the knowledge of the wage rates within each crop-cycle could be justified as being set by contractual arrangements. Given that the demand for labor in the second stage of production cannot be known in advance because of weather uncertainty, both (net) buyers and sellers of labor each year face uncertainty about wage rates in the harvesting season. A risk-averse individual from a labor exporting household would find it optimal to enter into a contract that sets the second stage wage rate in advance. Similarly, a net buyer (importer) of labor would find it optimal to enter into a contract so as to ensure that labor will be available when needed.

enter the information set of the household allowing one to treat the future path of wages as uncertain. Denoting the discount factor by β and the conditional expectation operator by E_t, the maximization problem of a rural household may be expressed as choosing C(t), M(t), F(t), m(t), f(t), so as to

$$\text{Max } E_1 \sum_{t=1}^{T} \beta^{t-1} U[C(t), M(t), F(t)], \tag{3}$$

subject to the asset accumulation and time constraints:

$$\bar{A}(t+1) = (1+r)A(t), \tag{4a}$$

$$M(t) + H_m(t) = T_m, \tag{4b}$$

$$F(t) + H_f(t) = T_f, \tag{4c}$$

$$A(1) = \text{a given number, and } A(T+1) = 0, \tag{4d}$$

where $1+r$ is the (gross) real interest rate, $\bar{A}(t)$ and $A(t)$ is the value of real assets held at the beginning and at the end of period t, H(t) is total hours of work on the farm and off the farm and T is the total time endowment.

More specifically, the assets held at the end of stage 1 (t an odd number) are described by the expression,

$$A(t) = \bar{A}(t) + \hat{W}(t) - \hat{C}(t) - W_m(t)m(t) - W_f(t)f(t) - p(t)K(t),$$

where $\hat{W}(t) = W_m(t)T_m + W_f(t)T_f$ is the value of time endowment in period t in real terms, with $W_m(t)$ and $W_f(t)$ being the real wage of males and females respectively, $\hat{C}(t) = C(t) + W_m(t)M(t) + W_f(t)F(t)$, is the value of consumption and leisure in real terms, and p(t) is a vector of relative prices of other fixed inputs.

The assets held at the end of stage 2 (t an even number) are given by:

$$A(t) = \bar{A}(t) + \hat{W}(t) + \Pi(t) - \hat{C}(t),$$

where $\Pi(t)$ denotes profits described by the expression,

$$\Pi(t) = \Gamma_t[m(t), f(t), m(t-1), f(t-1), \epsilon(t)] - W_m(t)m(t) \\ - W_f(t)f(t).$$

The first-order necessary conditions in the planting stage (t=odd) are as follows:

$$(5)\qquad U_C(t)=\lambda(t),$$

$$(6a)\qquad U_M(t)=\lambda(t)W_m(t),$$

$$(6b)\qquad U_F(t)=\lambda(t)W_f(t),$$

$$(7)\qquad \lambda(t)=(1+r)\beta\ E_t[\lambda(t+1)],$$

$$(8a)\qquad \lambda(t)W_m(t)=(1+r)\ \beta\ E_t[\lambda(t+1)\ (\frac{\partial Q(t+1)}{\partial m(t)}\quad \frac{\partial Q(t+1)}{\partial m(t+1)}\frac{\partial m^0(t+1)}{\partial m(t)}$$

$$+\frac{\partial Q(t+1)}{\partial f(t+1)}\frac{\partial f^0(t+1)}{\partial m(t)}-W_m(t+1)\frac{\partial m^0(t+1)}{\partial m(t)}-W_f(t+1)\frac{\partial f^0(t+1)}{\partial m(t)})],$$

$$(8b)\qquad \lambda(t)W_f(t)=(1+r)\ \beta\ E_t[\lambda(t+1)(\frac{\partial Q(t+1)}{\partial f(t)}+\frac{\partial Q(t+1)}{\partial m(t+1)}\frac{\partial m^0(t+1)}{\partial f(t)}$$

$$+\frac{\partial Q(t+1)}{\partial f(t+1)}\frac{\partial f^0(t+1)}{\partial f(t)}-W_m(t+1)\frac{\partial m^0(t+1)}{\partial f(t)}-W_f(t+1)\frac{\partial f^0(t+1)}{\partial f(t)})],$$

where $\lambda(t)$ is the Lagrangean multiplier associated with the period t asset accumulation constraint (4a). The term $\lambda(t)$ represents the marginal utility of wealth in period t (Heckman & MaCurdy, 1980).

Similarly the first-order necessary conditions for the harvesting periods (t=even) are identical to eq. (5)-(7) whereas harvesting labor is now chosen according to:

$$(9a)\qquad \lambda(t)[\frac{\partial Q(t)}{\partial m(t)}-W_m(t)]=0,$$

$$(9b)\qquad \lambda(t)[\frac{\partial Q(t)}{\partial f(t)}-W_f(t)]=0.$$

In short, equations (5) and (6) summarize the usual "static" conditions that must be satisfied by utility maximization within each period. Similarly, equations (9) correspond to the usual static first-order condition of profit maximization. These latter conditions are a consequence of the assumption that in the harvesting stage there is no uncertainty with respect to output.

The remaining equations summarize the conditions that must be satisified across time. Equation (7) is the "stochastic Euler equation" for the marginal utility of wealth $\lambda(t)$ and it suggests that the marginal utility of wealth follows a random walk (possibly with drift). Equations (8) characterize the optimal input choices in the planting stage. In contrast to the harvesting stage, the labor input choices of the household in stage 1 depend on $\lambda(t)$ and $E_t(\lambda(t+1))$ and thus indirectly on the preferences of the household. This is similar to the nonseparability result of Roe and Graham-Tomasi (1986). In the presence of risk aversion and in the absence of an effective means of insuring consumption against different states of nature, the consumption and labor supply decisions of the household interact with the labor used on the farm.

III. Empirical Analysis

A. Data

The panel data used are from three villages (Aurepalle, Shirapur and Kanzara) in the semi-arid region of India. These villages were part of the Village Level Study (VLS) conducted by the International Crops Research Institute for The Semi-Arid Tropics (ICRISAT). Resident investigators interviewed a stratified random sample of 30 cultivator and 10 labor households in each village every two to four weeks starting in May 1975 up until June 1984.[4]

The data for the estimation of the labor demand side of the model are extracted from Plot and Cultivation file. This file records input-output data for each plot by operation. It also includes information on the characteristics of each plot such as soil type, ownership and irrigation status, and cropping patterns. The observations for each operation performed on each plot operated by each household during each crop-cycle are aggregated into two household-level observations, one for each stage of the crop-cycle. Stage one corresponds to the preharvest operations: land preparing, planting, seeding, weeding, irrigating, etc. Stage two corresponds to harvesting operations including threshing. The time period covered by stage one is longer than that of stage two and the duration of each stage varies from crop cycle to crop cycle and from village to village.

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[4] For a detailed description of the VLS data set the reader is referred to Singh, Binswanger and Jodha (1985) and Walker and Ryan (1989).

A balanced panel sample with 414 observations is used for the estimation of the production side of the model using household level input-output information from the rainy (kharif) and post-rain (rabi) seasons for 46 households for 9 crop cycles. On the production side, village level wage rates are constructed for males (and females) for each stage by summing total cash and kind payments to males (females) in each stage and dividing this sum by the total male (female) hours worked in each stage in each village.

The labor supply side of the model is estimated using the Labor, Draft Animal and Machinery Utilization file. This file records both on- and off-farm activities, collected on a two to four week "full recall basis" starting in 1979. Data for male heads of household and their spouses are extracted and matched to their individual and household characteristics contained in the Characteristics file.

The observations on labor allocation of male heads of households and spouses of heads of households are aggregated to correspond to the planting and harvesting stage of the labor demand side of the model.[5] Only the last five years of the labor supply file are used since wages received by each individual and by source were not recorded for the years prior to 1979. These procedures led to a balanced panel of 51 male heads of households and 61 spouses for 10 crop cycles (20 stages). The measure of total hours of work offered is constructed by summing the hours worked on own farm with hours worked for other other farmers, hours worked in government sponsored projects, hours worked in non-government projects and hours of involuntary unemployment. To adjust for the difference in the length of each stage, the average hours of work offered per month in each stage is used. For further details on sample means and variances see Skoufias (1988).

B. Econometric Specification

Estimation of the labor supply and labor demand choices implied by the first-order conditions above is carried out using the λ-constant framework initially proposed by MaCurdy (1981, 1985). This approach yields functions for labor supply and labor demand that decompose current decisions at any point in time into two components. The first component consists of a set of variables observed in the current period such as wages and other prices, while the second component is the marginal utility of wealth $\lambda(t)$ that summarizes the influence on current decisions

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[5] For more details the reader is referred to Skoufias (1988).

of all past and (expected) future events. An essential element of the empirical specification is that the marginal utility of wealth enters linearly in the decision rules.

Assuming a utility function that is additively separable in consumption, male and female leisure, the λ-constant labor supply functions implied by conditions (6) above for male (m) and female (f) members, indexed by subscript k, in household i in period t may be specified as

$$(10) \qquad \ln H_{ki}(t) = F_k(\ln\lambda_i(t)) + \beta_k \ln W_{ki}(t) + \gamma_k X_{ki}(t) + \upsilon_{ki}(t)$$

where $F_k(\ln\lambda_i(t))$ is a linear function of the logarithm of $\lambda_i(t)$, the marginal utility of wealth of household i in period t, β_k is the intertemporal substitution elasticity of labor supply, γ_k is a vector of parameters summarizing the influence of observed individual characteristics $X_{ki}(t)$, and $\upsilon_{ki}(t)$ is an error term summarizing the role of unobserved taste factors.[6] In general, the marginal utility of wealth included in $F_k(\ln\lambda_i(t))$ is a function of all current, future and past values of wages and profits, initial assets and all individual and household characteristics.

In the context of the seasonal model considered here, β_k is the elasticity relevant for predicting how an individual's labor supply responds to changes in wages arising from perfectly anticipated seasonal fluctuations. Note that β_k is also approximately equal to an unanticipated seasonal change in the wage rate to the extent that such a change is temporary and does not warrant revising the initial value of the marginal utility of wealth.

Direct estimation of equations (10) encounters three major problems. First, $\lambda_i(t)$ is unobservable and potentially correlated with the included regressors. Therefore, it would be inappropriate to include it in the error term of the regression as this would lead to simultaneity bias. Second, simultaneity bias may also arise from the possible correlation of the unobservables influencing hours worked and wage rates; i.e. $\upsilon_{ki}(t)$ and $W_{ki}(t)$ may be correlated. Third, wage data for individuals who worked only in their own farms and did not work for others are not available.

To control for the first potential source of simultaneity, equations (10) are estimated in first-difference form, since first-differencing

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[6] For examples of explicit functional forms of the underlying utility function see MaCurdy (1981).

removes the unobservable $\ln\lambda_i(t)$ from the regression. The other two problems are addressed by using the gender-specific village average wage rates in place of individual wage rate earned. This is justified on the grounds that estimation of gender-specific wage functions in earlier stages of this research revealed that observed individual characteristics such as age and education were not significant and sample selection bias was not present.

Thus the labor supply equations estimated for males and females are:

$$\Delta\ln H_{ki}(t)=\alpha_k+\beta_k\ \Delta\ln W_k^v(t)+\gamma_k\Delta X_{ki}(t)+\eta_{ki}(t) \tag{11}$$

where Δ is the first difference operator, α_k is a constant term involving the difference between the rate of time preference and the interest rate r, W_k^v is the gender-specific village average wage rate, and $\eta_{ki}(t)=\Delta\upsilon_{ki}(t)$.

A significant advantage of the preceding formulation, and the λ-constant framework in general, is the relative ease of accounting for uncertainty in the empirical analysis. Removal of the conditional expectation operator from the Euler equation for the marginal utility of wealth (see equation (7) above) yields

$$\lambda_i(t)=\frac{\beta^{-1}}{(1+r)}\lambda_i(t-1)[1+u_i(t)],$$

where $u_i(t)$ is a forecast error which, under rational expectations, has a zero mean conditional on the information set at $t-1$. This implies that in the case of uncertainty, the error term of the regression will include the logarithm of the forecast error of the marginal utility of wealth, i.e.

$$\eta_{ki}(t)=\Delta\upsilon_{ki}(t)+\ln(1+u_i(t)].$$

Thus, uncertainty may be acocunted for using instrumental variables that are uncorrelated with the current period forecast error of the marginal utility of wealth in the current period. A natural criterion for the selection of instrumental variables is variables dated $t-1$ or earlier. Moreover, one may conduct a formal test of the uncertainty vs. perfect foresight specification. Using lagged first differences of past village wage rates (e.g. $\Delta\ln W_k^v(t-1)$, $\Delta\ln W_k^v(t-2)$ etc.) as instrumental variables for $\Delta\ln W_k^v(t)$ one can conduct an exogeneity test (Hausman, 1978) for possible correlation between $\Delta\ln W_k^v(t)$ and $\eta_{ki}(t)$.

On the production side it is assumed that the single stage production functions (2a) and (2b) are Cobb-Douglas. Despite the well known technological restrictions it imposes, the Cobb-Douglas specification is used since recursive substitution of the single stage functions yields a composite production function also of Cobb-Douglas form (Antle, 1983). In addition one can obtain explicit solutions for the input demand functions.

The presentation in the remainder of this section will be reduced to two periods (stages) since on the production side the interdependence of input decisions occurs within the two stages of each crop-cycle and not across crop-cycles. The "composite production function" for farmer i is specified as:

$$Q_i(2) = \delta_0 f_i(2)^{\delta_1} m_i(2)^{\delta_2} f_i(1)^{\delta_3} m_i(1)^{\delta_4} K_i(1)^{\delta_5} \exp(\epsilon_i(2)) \tag{13}$$

where the δ_j's are (nonlinear) functions of the single stage production function parameters. In stage 2 the choice of labor is based on the static profit maximization conditions (9). Solving these FONC with respect to $f_i(2)$ and $m_i(2)$, and taking logs yields the following "reduced forms" for the male and female labor demand functions in the harvesting stage (ignoring constant terms):

$$\begin{aligned} \ln m_i(2) = {} & \mu_{12} \ln f_i(1) + \mu_{22} \ln m_i(1) + \mu_{23} \ln W_m(2) \\ & + \mu_{24} \ln W_f(2) + \mu_{25} \ln K_i(1) + \epsilon^m(2), \end{aligned} \tag{14a}$$

$$\begin{aligned} \ln f_i(2) = {} & \phi_{12} \ln f_i(1) + \phi_{22} \ln m_i(1) + \phi_{23} \ln W_m(2) \\ & + \phi_{24} \ln W_f(2) + \phi_{25} \ln K_i(1) + \epsilon_i^f(2), \end{aligned} \tag{14b}$$

where the coefficients μ and ϕ are functions of the underlying production function parameters, and ϵ_i (2) is a disturbance term including the realized shock to the standing crop observed by the farmer, as well as all other unobservables.[7]

Inspection of (14) indicates that the amount of male and female labor utilized in the second stage is simultaneously determined with output since the actual value of the random term $\epsilon(2)$ affecting output in the second stage, also affects the choice of inputs in the second stage. This also suggests that direct estimation of the composite agricultural production function described by expression (13) will yield biased and inconsistent parameters since some of the right hand side variables

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[7] The underlying production function parameters imply the following cross-equation coefficient restrictions: $\phi_{21} = \mu_{21}$, $\phi_{22} = \mu_{22}$, $\phi_{25} = \mu_{25}$, and $\mu_{24} - \phi_{24} = \phi_{23} - \mu_{23} = 1$.

(namely f(2) and m(2)) are not independent of the disturbance in the production function (Mundlak, 1963; Antle, 1983). On the other hand, one can directly estimate expressions (14) since all the inputs chosen in the first stage are independent of $\epsilon(2)$; first stage inputs are chosen based on the conditional expectation of $\epsilon(2)$.

Next, the sequential interdependence of decisions amounts to farmers knowing the dependence of the harvesting input choices on both f(1) and m(1) as described by equations (14). Substituting f(2) and m(2) by equations (14) into (13) and then using conditions (8) that determine the optimal input choices in the planting stage, yields the following "reduced forms" (in logs) for labor demand in the planting stage (ignoring constant terms):[8]

$$\begin{aligned} \text{(15a)} \quad \ln m_i(1) = {} & \mu_{11}\ln W_m(1) + \mu_{12}\ln W_f(1) + \mu_{13}\ln W_m(2) \\ & + \mu_{14}\ln W_f(2) + \mu_{15}\ln K_i(1) + \upsilon_i^m(1), \end{aligned}$$

$$\begin{aligned} \text{(15b)} \quad \ln f_i(1) = {} & \phi_{11}\ln W_m(1) + \phi_{12}\ln W_f(1) + \phi_{13}\ln W_m(2) \\ & + \phi_{14}\ln W_f(2) + \phi_{15}K_i(1) + \upsilon_i^f(1), \end{aligned}$$

where $\upsilon_i^k(1) = \Gamma\ln\{E_1[\frac{\lambda_i(2)}{\lambda_i(1)}\exp(\epsilon_i(2))]\}$.[9] Equations (15) illustrate the problem of nonseparability mentioned. The terms $\upsilon_i^k(1)$ in the planting stage input demand functions are functions of the household consumption choices as represented by the term $\lambda(t)$ $(=U_C(t))$. This is a direct consequence of uncertainty and risk aversion in consumption and has important implications on the estimation method that is appropriate to use. As discussed previously, the unobservable marginal utility of wealth in each period is a complicated function of past, current and future wages (among others). This results in correlation between the error terms and the right hand side variables suggesting the presence of simultaneity (nonseparability) bias. If one were to use an estimator, such as ordinary least squares (OLS), that does not control for such correlations then the derived estimates would be biased.

In this study it is argued that under the conditions specified below, inclusion of farmer-specific dummies or, more generally, application of the fixed-effects estimator will eliminate the nonseparability bias arising in the case of uncertainty with risk aversion. This can be demonstrated

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[8] It is assumed that $\epsilon(t+1) \sim N(0, \sigma^2)$, which implies $E_t(\exp(\epsilon(t+1)) = E_t(\exp(\sigma^2/2))$.

[9] The corresponding cross-equation restrictions are: $\phi_{13}=\mu_{13}$, $\phi_{14}=\mu_{14}$, $\phi_{15}=\mu_{15}$, and $\mu_{12}-\phi_{12}=\phi_{11}-\mu_{11}=1$. Note also that $\Gamma=\Delta-\delta_3-\delta_4$.

as follows. The first-order conditions (1)-(9) may be utilized so as to express the conditional expectation term included in $\upsilon_i^k(1)$ which enters equations (15) above, as:

$$E_1[\frac{\lambda_i(2)}{\lambda_i(1)} \exp(\epsilon_i(2))] = E_1\{\frac{\lambda_i(2)}{\lambda_i(1)}\}E_1\{\exp(\epsilon_i(2))\}$$

$$+ COV_1\{\frac{\lambda_i(2)}{\lambda_i(1)}, \exp(\epsilon_i(2))\}.$$

The Euler equation (eq. (6) above) implies that

$$E_1\{\frac{\lambda_i(2)}{\lambda_i(1)}\} = E_1\{\frac{U_C(2)}{U_C(1)}\} = \frac{\beta^{-1}}{(1+r)}.$$

If ϵ_i (2) were distributed normally with zero mean and variance σ_i^2, as assumed by the theoretical model, then the conditional expectation term (ignoring Γ) reduces to:

$$\ln E_1[\frac{\lambda_i(2)}{\lambda_i(1)} \exp(\epsilon_i(2))] = \ln[\frac{\beta^{-1}}{(1+r)} \exp(\sigma_i^2/2) + \rho_i]$$

where ρ_i is a time-invariant farmer-specific term[10] denoting the covariance between $\frac{\lambda_i(2)}{\lambda_i(1)}$ and exp (ϵ_i (2)).[11]

To account for omitted variable bias in the planting stage equations as well the role of other random disturbances, the unobserved term $\upsilon_i^k(t)$ at each planting period t may be approximated as the sum of three distinct components such as

$$\upsilon_i^k(t) = \mu_i^k + \tau^k(t) + \zeta_i^k(t),$$

where k indexes males and females. The first term μ_i^k, which is time-invariant, captures farmer-specific heterogeneity that can arise from the omission of variables such as σ_i^2 and ρ_i, farmer managerial ability, and farmer-specific discount factors and interest rates. Farmer-specific in-

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[10] The conditional covariance term is time invariant when the joint distribution of vector of random variables follows a multivariate stationary normal distribution (e.g. see Hansen and Singleton, 1983).

[11] Note that separability would result, if the within-period utility function, in addition to being additively separable in consumption and leisure, were linear in consumption. Linearity in consumption, which is amounts to risk neutrality, implies that $\rho_i = 0$.

terest rates, in particular, could arise if credit markets were imperfect. The term $\tau^k(t)$ captures all time-specific shocks affecting all households in the same manner and can also be interpreted as a control for intertemporal changes in the market interest rate. In the regressions below, the term $\tau^k(t)$ is accounted for by including year-specific dummy variables in each labor demand regression. The third term, $\zeta_i^k(t)$, includes random shocks to the demand for labor in the planting stage that vary across households and time. It is assumed that $\zeta_i^k(t)$ has zero mean and constant variance, it is uncorrelated over time and farmers and uncorrelated with all regressors. Thus, there is no serial correlation (or heteroskedasticity) beyond that which arises from the presence of the farmer-specific and year-specific components.

With the preceding assumptions the appropriate estimator for the labor demand equations in the planting stage is determined by the treatment of the farmer-specific components μ_i^k. The fixed-effects specification allows μ_i^k to be correlated with the included regressors whereas the random-effects specification treats μ_i^k as uncorrelated with the included regressors. The empirical analysis below reports test statistics from Hausman (1978) tests of the random-effects versus fixed-effect specification.

C. Results

Estimation of the intertemporal labor supply functions (eq. 11) is carried out by including dummy variables for each time period in the sample. Alternative justifications for the inclusion of the year dummies are the need to account for the presence of preference shocks common to all households and the possibility that the market interest rate r included in the constant term α_k may vary across time (assuming perfect credit markets).

Possible elements of the vector X(t), containing the observed factors affecting tastes toward work, might include the age of the individual, the education of the individual, his/her caste, the number of children, the size of the household, the level of rainfall and the stage in the current crop-cycle. Since the estimation is carried out on first-differences which removes the unobservable marginal utility of wealth, the effects of all time-invariant elements of X(t) are also removed. The two time varying variables included in the regressions are: the number of children adjusted for household size and rainfall. A dummy variable taking the value 1 for the harvesting stage in each crop-cycle is also included.

Table 1 contains estimates of the intertemporal elasticity of substitu-

Table 1

MALE AND FEMALE LABOR SUPPLY (eq. 11): PERFECT FORESIGHT (Stand Errors)

Indep. Var.	**MALES**		**FEMALES**	
First difference in:				
Ln of village MALE wage/hr	−0.201 (0.287)	−0.4818 (0.308)	—	—
Ln of village FEMALE wage/hr	—	—	1.849 (0.329)	1.597 (0.360)
Dummy for stage	—	−0.122 (0.252)	—	−0.951 (0.408)
Rainfall (mm's)	—	−0.009 (0.003)	—	−0.004 (0.004)
Number of children	—	0.559 (0.377)	—	−0.236 (0.505)
Intercept	0.317 (0.189)	0.484 (0.182)	0.447 (0.223)	0.514 (0.238)
Time Dummies	YES	YES	YES	YES
No. of Obs	969	918	1159	1098
SSE	1551.7	1396.8	3441.9	3352.8
F-value	1.44	2.12	3.20	2.6
R-squared	0.0279	0.0452	0.051	0.0474

tion for male heads of households (β_m), and spouses of heads of households (β_f) respectively under perfect foresight.[12] These estimates suggest that there is no significant intertemporal trade-off in the labor supply of males. This result may be due to the fact that the major function of male heads is supervision and management of the day-to-day farm operations. There would be limited possibilities for intertemporal substitution, since management and supervision are required in certain amounts every period, like fixed inputs.

However, there is evidence of intertemporal substitution of labor supply for females. These estimates are positive and strongly siginficant

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[12] Use of imputed individual wage rates based on selectivity corrected wage function parameters yielded very similar results. Note also that equations (1) were estimated separately for males and females.

under both specifications. In addition, all estimates have values much larger than the estimates derived for females in the U.S. using yearly microeconomic panel data (MaCurdy, 1981). This is an anticipated result. The duration of each time period in this study is short (2-3 months). Leisure (or labor supply) is likely to be more intertemporally substitutable across shorter periods of time than it would be across longer ones. The maximization of discounted expected utility, thus leads households to allocate labor supply over time in such a way that more female labor is supplied during periods of high wage rates and less is supplied in the periods of low wage rates.[13]

As discussed in the previous section, the case of uncertainty can be dealt with appropriate instrumental variables. The instruments used for the first difference of the current village wage for females ($\Delta\ln W_f(t)$) were the first, second, third and fourth lagged first differences of the village wage rates for females (i.e. $\Delta\ln W_f(t-1)$, $\Delta\ln W_f(t-2)$, $\Delta\ln W_f(t-3)$, $\Delta\ln W_f(t-4)$). Table 2 contains the instrumental variable estimates of the intertemporal elasticity for females. The corresponding estimates for males are not reported since the obtained estimates of β_m were still negative and insignificant. Under uncertainty the estimated intertemporal elasticity of substitution becomes even larger when compared to Table 1. A Hausman exogeneity test of the first difference in the village female wage rate rejected the hypothesis of exogeneity. In all specifications reported in Table 2 the t-value of the estimated residual from the first stage regression was greater than 3.5.

Estimation of the labor demand functions for planting (eq. 15) and harvesting (eq. 14) is carried out by treating male and female labor hours in each stage as the only variable inputs. Additional inputs in the first stage of production are the area cultivated, seeds, fertilizers, pesticides, machines and bullocks. These are aggregated into one composite input called "other inputs." Given the homogeneity of degree zero of input demand functions, all inputs measured in value terms and all hourly wage rates were normalized by dividing them by the village specific CPI. The village specific CPI is used a measure of the price of the composite agricultural commodity consumed and produced. Finally, the proportion of the cultivated area that is irrigated was also included as a shifter in the input demand functions.

As noted earlier in the paper, estimation of the second stage labor

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[13] However, this statement needs to be qualified since cross wage effects are ignored. The results of Rozenzweig (1980) suggest that such cross wage effects between male and female labor supply of Indian rural households may be quite strong. This issue certainly deserves more attention in a further study.

Table 2

FEMALE LABOR SUPPLY (eq. 11): UNCERTAINTY
(Standard Errors)

Indep. Var	**(a)**	**(b)**
First difference in:		
Ln of village FEMALE wage/hr[a]	3.229	2.721
	(0.486)	(0.538)
Dummy for stage	—	−0.012
		(0.350)
Rainfall (mm's)	—	−0.010
		(0.004)
Number of children	—	−0.180
		(0.567)
Intercept	−0.403	−0.532
	(0.221)	(0.233)
Time Dummies	YES	YES
No. of Obs	915	854
SSE	2676.6	2581.8
F-value	4.73	4.02
R-squared	0.0732	0.0714

Note: Instrumental variables: lagged first difference of the female village level wage rate for the last four time periods.

demand equations (eq. 14) can be carried out with relative ease since all the first stage inputs and second stage wage rates are independent of the production disturbance term ($\epsilon(2)$). However, it is possible that a correlation may still be present among the first stage inputs and the disturbance term of the second stage labor demand equation due to heterogeneity in unobservable managerial abilities of farmers (Mundlak (1961)). In order to test and control for the presence of such a bias, the fixed-effects estimator is also applied in the estimation of the harvesting labor demand functions.

Given that the labor demand functions for each stage are derived from an underlying technology, one has to take into consideration the following additional factors: a) the error terms in the reduced form system in each stage, may be correlated even after the removal of the fixed-effects; and b) the relations between the parameters of the reduced form system in each stage.

In order to account for these two factors the labor demand functions in each stage are estimated by imposing the linear cross-equation restrictions implied by the underlying technology parameters.[14,15] Thus, for the harvesting stage, the two-equation system described in (14) is estimated by expressing each variable in deviation form (from the farm mean) and imposing the linear cross-equation restrictions. The results obtained from using the SUR estimator of Zellner (1962) with cross-equation restrictions are presented in Table 3. The corresponding estimates obtained for the planting stage (eq. 15) labor input use are presented in Table 4.

Table 3 and 4 also contain the restricted OLS estimates obtained by simply imposing the cross-equation restrictions in each stage but without controlling for farmer fixed-effects. According to the preceding arguments, these estimates may be biased, since they ignore the correlation of the error term with the right hand side variables in each equation (heterogeneity and nonseparability bias).

Comparison of the results under ordinary least squares (perfect foresight and no heterogeneity) and fixed-effects (heterogeneity and/for risk) reveals that accounting for heterogeneity and/or nonseparability has a drastic effect on the sign of the estimated parameters. For example, after accounting for fixed-effects the sign of the own wage elasticity for female labor reverses. In general, the fixed-effects estimates yield the anticipated signs for both males and females in both stages.

In the planting stage the fixed-effects estimates of the elasticity of female labor demand with respect to the current village level female wage rate suggest that the demand for female labor (or the tasks performed by female labor) is elastic whereas the corresponding elasticity for males is very low. This result in combination with the high intertemporal elasticity of substitution of females provides further proof of the importance of accounting for heterogeneity in the rural sector of developing countries.

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[14] The interest in this paper is in the estimation of consistent elasticities. Several attempts were made at deriving the underlying technology parameters (the δ_j's) using non-linear methods as in Antle and Hatchett (1986), without any success due to collinearity problems.

[15] Note that Wald tests of the validity of the cross-equation linear restrictions rejected the null hypothesis. However due to lack of a better alternative, it was decided to present the estimates obtained after the imposition of the restrictions.

Table 3

MALE AND FEMALE LABOR DEMAND IN THE HARVESTING STAGE
(Standard Errors)

Indep. Var.	MALES: (Eq. 14a) OLS	MALES: (Eq. 14a) Fixed-Eff.	FEMALES: (Eq. 14b) OLS	FEMALES: (Eq. 14b) Fixed-Eff.
Ln hrs of FEMALE labor in Stage 1	0.069 (0.035)	−0.057 (0.038)	0.069 (0.035)	−0.057 (0.038)
Ln hrs of MALE labor in Stage 1	0.469 (0.087)	0.252 (0.084)	0.469 (0.087)	0.252 (0.084)
Ln village MALE WAGE (/hr) in Stage 2	−0.634 (0.138)	−0.759 (0.298)	0.365 (0.138)	0.240 (0.298)
Ln village FEMALE WAGE (/hr) in Stage 2	1.111 (0.192)	0.644 (0.222)	0.111 (0.192)	−0.356 (0.222)
Ln cultivated area (acres)	0.392 (0.104)	0.564 (0.110)	0.392 (0.104)	0.564 (0.110)
Ln other inputs (1975 Rs.)	0.118 (0.067)	0.152 (0.069)	0.118 (0.067)	0.152 (0.069)
Proportion of are irrigated	0.363 (0.311)	0.740 (0.362)	0.363 (0.311)	0.740 (0.362)
Intercept	0.866 (0.404)	—	0.778 (0.399)	—
Yr Dummies 1976-1983)	YES	YES	YES	YES
SSE	425.139	271.269	317.915	199.04
F-test:	—	2.708	—	3.789
Hausman's $\chi^2(7)$:		24.14		29.51

Note: These estimates are obtained after imposing the linear cross-equation restrictions implied by the underlying Cobb-Douglas production function.

In the harvesting stage, both own price elasticities are less than one (in absolute value) suggesting inelastic demand for both male and female labor. The positive cross-wage elasticities for male and female labor in that stage suggest that males and females act as substitutes for each other.

Table 4

MALE AND FEMALE LABOR DEMAND IN THE PLANTING STAGE
(Standard Errors)

	MALES: (Eq. 15a)		FEMALES: (Eq. 15b)	
Indep. Var.	**OLS**	**Fixed-Eff.**	**OLS**	**Fixed-Eff.**
Ln village MALE WAGE/hr in Stage 1	0.938 (0.202)	0.261 (0.201)	1.938 (0.202)	1.261 (0.201)
Ln village FEMALE WAGE/hr in Stage 1	0.467 (0.099)	−0.146 (0.118)	−0.533 (0.099)	−1.146 (0.118)
Ln village MALE WAGE/hr in Stage 2	−1.09 (0.190)	−0.651 (0.259)	−1.09 (0.190)	−0.651 (2.259)
Ln village FEMALE WAGE/hr in Stage 2	0.636 (0.110)	0.313 (0.139)	0.636 (0.110)	0.313 (0.139)
Ln Cultivated area (in acres)	0.698 (0.053)	0.724 (0.057)	0.698 (0.053)	0.724 (0.057)
Ln other inputs (1975 Rs.)	0.413 (0.040)	0.339 (0.040)	0.413 (0.040)	0.339 (0.040)
Proportion of area irrigated	1.062 (0.171)	0.933 (0.215)	1.062 (0.171)	0.933 (0.215)
Intercept	2.491 (0.225)	—	1.055 (0.260)	—
Yr Dummies (1976-1983)	YES	YES	YES	YES
SSE	78.39	57.318	698.145	280.166
F-test:	—	2.859	—	4.421
Hausman's $\chi^2(7)$:	—	33.58	—	51.59

Note: These estimates are obtained after imposing the linear cross equation restrictions implied by the underlying Cobb-Douglas production function.

In the planting stage, however, the cross-price effects reveal a different picture. Increases in current male wage rates appear to have a significant positive effect on female labor demand whereas increses in female wage rates are associated with small decreases in male labor demand. This is an interesting result that reflects the gender specificity of agricultural tasks in the planting stage (Bardhan, 1984). Furthermore, these estimates imply that it is female labor that will substitute for male tasks but not the other way around.

As the values of the F-test statistics in Tables 3 and 4 indicate, the hypothesis that the constant terms are identical across farms is rejected at the conventional significance levels in all cases.[16] One possible reason for the significance of farm fixed-effects may be strictly due to heterogeneity in managerial skills or soil quality. An additional reason may be the presence of the marginal utility of wealth in the labor demand functions. Finally, the random-effects versus fixed-effects specification tests were conducted along the lines suggested by Hausman (1978). The hypothesis that the error terms are uncorrelated with the regressors is also rejected for both male and female labor demand in each stage. Note that the Hausman test results, while consistent with the hypothesis that risk aversion leads to nonseparability (simultaneity) bias, they do not provide conclusive evidence in favor of the importance of risk in agricultural decision making. The correlation between the error term and the included regressors may be solely due heterogeneity. However, as the discussion above suggests, risk provides an additional reason for the use of fixed-effect estimator.

IV. Concluding Remarks

Most studies of labor demand and labor supply in rural areas of developing countries ignore risk and the seasonal nature of agriculture. This study constructs a dynamic/stochastic model of the farm household provides some of the first estimates of the intertemporal elasticity of substitution of the time worked by males and females between planting and harvesting as well as evidence on the extent to which wage elasticity estimates for male and female labor vary across planting and harvesting operations.

With respect to labor supply, the estimates obtained here suggest that there is little or no substitution of work time by males between planting and harvesting. On the other hand, family females seem to work relatively more hours during the harvesting season when the

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[16] A Hausman test of the null hypothesis of equality of the slope coefficients of the ordinary least squares and fixed-effects estimators, also rejected the null for both males and females in each stage with year dummies.

marginal productivity of their time is higher relative to that in the planting season. This result provides further support to the argument that the correct measurement of unemployment in the rural sector of developing countries must distinguish between the "usual" labor force and the "current" labor force (Bardhan, 1978).

On the labor demand side, the estimated wage elasticities during harvesting were found to be quite different compared to planting, for both male and female labor. In particular, the demand for female labor is elastic during planting but quite inelastic during harvesting. In contrast, the demand for male labor is wage inelastic in both planting and harvesting.

The estimated wage elasticities from the model suggest that the response of rural wages and employment to shifts in the demand for or supply of labor differ substantially from season to season. Moreover, the effects of policies aimed at shifting the demand or supply of labor will have a different impact on household income and welfare depending on the gender composition of the household. Future micro studies of rural households must certainly take into consideration such inter-linkages between seasonal and socio-economic features of agrarian economies.

References

Altonji, J. and A. Siow, "Testing the Response of Consumption to Income Changes with (Noisy) Panel Data," *Quarterly Journal of Economics,* 102, 1987, 293-328.

Antle, J.M., "Sequential Decision Making in Production Models," *American Journal of Agricultural Economics,* 65, 1983, 282-290.

_____ and S.A. Hatchett, "Dynamic Input Decisions in Econometric Production Models," *American Journal of Agricultural Economics,* 68, 1986, 939-949.

Bardhan, K., "Work Patterns and Social Differentiation: Rural Women of West Bengal," in H.P. Binswanger and M.R. Rosenzweig (eds.), *Contractual Arrangements, Employment, and Wages in Rural Labor Markets in Asia,* Yale University Press, New Heaven, 1984.

Bardhan, P.K., "On Measuring Rural Unemployment," *Journal of Development Studies,* 14, 1978.

_____, "Wages and Unemployment in a Poor Agrarian Economy: A Theoretical and Empirical Anlaysis," *Journal of Political Economy,* 87, 1979, 479-500.

Barnum, H.N. and L. Squire, "An

Econometric Application of the Theory of the Farm Household," *Journal of Development Economics,* 6, 1979, 79-102.

Benjamin, D., "Household Composition, Labor Markets and Labor Demand: Testing for Separation in Agricultural Household Models," *Econometrica,* 60, 1992, 287-322.

Binswanger, H.P., "Attitudes toward Risk: Experimental Measurement in Rural india," *American Journal of Agricultural Economics,* 62, 1980, 395-407.

_____ and M.R. Rosenzweig, "Behavioral and Material Determinants of Production Relations in Agriculture," *Journal of Development Studies,* 22, 1986, 503-539.

Chambers, R., "Health, Agriculture and Rural Poverty: Why Seasons Matter," *Journal of Development Studies,* 18, 1982, 217-238.

Hansen, R. and K. Singleton, "Stochastic Consumption, Risk Aversion and the Temporal Variation of Assets," *Journal of Political Economy,* 91, 1983, 249-265.

Hausman, J., "Specification Tests in Econometrics," *Econometrica,* 46, 1978, 1251-1270.

Heckman, J.J. and T.E. MaCurdy, "A Life-Cycle Model of Female Labor Supply," *Review of Economic Studies,* 47, 1980, 47-74.

Lopez, R.E., "Estimating Labor Supply and Production Decisions of Self-Employed Farm Producers," *European Economic Review,* 24, 1984, 61-82.

MaCurdy, T.E., "An Empirical Model of Labor Supply in a Life-cycle Setting," *Journal of Political Economy,* 89, 1981, 1059-1085.

_____, "Interpreting Empirical Models of Labor Supply in an Intertemporal Framework with Uncertinty," in J.J. Heckman and B. Singer (eds.), *Longitudial Analysis of Labor Market Data,* Cambridge University Press, Cambridge, 1985.

Mundlak, Y. "Empirical Production Function Free of Management Bias," *Journal of Farm Economics,* 43, 1961, 44-56.

Pitt, M. and M. Rosenzweig, "Agricultural Prices, Food Consumption, and the Health and Productivity of Indonesian Farmers," in I. Singh, L. Squire and J. Strauss (eds.), *Agricultural Household Models: Extensions, Applications, and Policy,* Johns Hopkins University Press, Baltimore, 1986, 153-182.

Roe, T. and T. Graham-Tomasi, "Yield Risk in a Dynamic Model of the Agricultural Household," in I. Singh, L. Squire and J. Strauss (eds.), *Agricultural Household Models,* Johns Hopkins University Press, Baltimore, 1986, 255-276.

Rosenzweig, M.R., "Neoclassical Theory and the Optimizing Peasant: An Econometric Analysis of Market Family Labor Supply in a Developing Country," *Quarterly Journal of Economics,* 94, 1980, 31-55.

Ryan, J.G. and R.D. Ghodake, "Labor Market Behavior in Rural Villages in South India: Effects of Season, Sex and Socioeconomic Factors," in H.P. Binswanger and M.R. Rosenzweig (eds.), *Contractual Arrarngements, Employment and Wages in Rural Labor Markets in Asia,* Yale University Press, New Heaven, 1984.

Sahn, D., *Seasonal Variability in Third World Agriculture,* Johns Hopkins University Press, Baltimore,1989.

Singh, I., L. Squire, and J. Strauss (eds.), *Agricultural Household Models: Extensions, Applications and Policy,* Johns Hopkins University Press, Baltimore, 1986.

Singh, R.P., H.P. Binswanger, and N.S. Jodha, *Manual of Instructions for Economic Investigators in ICRISAT's Village Level Studies* (Revised), ICRISAT, Patancheru P.O., Andhra Pradesh 502 324, India, 1985.

Skoufias, E., "Dynamics of Labor Demand and Supply of Rural Households: A Theoretical and Empirical Analysis," Ph.D. Dissertation, University of Minnesota, 1988.

Walker, T. and J. Ryan, *Village and Household Economies in India's Semi-Arid Tropics,* Johns Hopkins University Press, Baltimore, 1990.

Zellner, A., "An Efficient Method for Estimating Seemingly Unrelated Regressions and Tests of Aggregation Bias," *Journal of the American Statistical Association,* 57, 1962, 348-368.