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A STATISTICAL ANALYSIS OF A PILOT SURVEY OF SALT-AFFECTED DAIRY FARMS

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A small stratified sample was drawn from irrigated dairy farms judged to exhibit two degrees (high and low) of salting in the soil. Cobb-Douglas production functions were fitted to time series and cross sectional data for each stratum. The results support the conclusion that the data from the two strata can be pooled and that the quality of the soil in this area can be modelled using an analysis of covariance approach. A preliminary confidence interval for the geometric mean of the ratio of the shadow price of water to the price of butterfat for farms in the sample was also calculated. This interval supports the hypothesis that rationed irrigation water is worth more to these farms than the price paid.

The estimation and analysis of production functions from a pilot survey of salt affected dairy farms in the Campaspe Irrigation District of Victoria are reported in this paper. The results obtained are of interest as an example of the way pilot studies can be used at the specification stage of analyses using production functions, and for the clues they provide about the nature of the production functions of these farms.

Most of the dairy farms in the Campaspe Irrigation District are salt affected and it is thought that excessive use of irrigation water can exacerbate the salting problem on these farms by raising the level of a salty water table. At present, the amount of irrigation water sold by the Rural Water Commission of Victoria (formerly the State Rivers and Water Supply Commission) in the Campaspe Irrigation District is restricted. Farms are entitled to purchase a basic amount of water (the 'water right') in all years, and an additional amount annually subject to availability.

Currently, the Commission charges a price for water which is cost based and which is changed annually in line with cost changes. The Commission believes that the value of irrigation water at the margin to Campaspe Irrigation District dairy farms at current levels of use is higher than the current price. The prima facie evidence for this is that most farms usually buy all of their water entitlement in most years. An estimate of the average of the ratio of the shadow price of water (at current levels of use) to the price of butterfat would provide some statistical evidence on this question and would also give some idea of how water use might respond to changes in the formula for pricing water. These issues are of some importance to policy makers.

A related question is whether output on all Campaspe Irrigation District dairy farms responds to inputs, particularly irrigation water, in the same way. This question can be examined statistically by testing for differences in the coefficients of the production functions for various

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strata in the sample. Any differences in the way the ouput of farms with different degrees of soil salting changes with the level of the input of irrigation water may have implications for policies or practices designed to alleviate salting problems.

Data from the pilot survey are used to test for the existence of strata in the production functions of farms in the sample and also to calculate a preliminary confidence interval for the geometric mean of the ratio of the shadow price of water to the price of butterfat of farms in the sample. The reported confidence interval is preliminary because it is calculated using statistics obtained from a regression model which was not specified a priori but was arrived at after some statistical testing. This point is discussed in some detail in the following section of the paper.

It was assumed that farmers operate on the stochastic Cobb-Douglas production function:

$$Y_{it} = A_{0i} \prod_{j=1}^{k} X_{itj}^{\beta_j} \exp\{u_{it}\} \tag{1}$$

$$(A_{0i} > 0,\ X_{itj} > 0,\ \beta_j > 0)$$

where A_{0i} represents fixed factors that are specific to firm i but are assumed to be randomly distributed across firms, X_{itj} is the level of factor j used by firm i in period t, and u_{it} is an independent and identically distributed random error term assumed to be distributed independently of all factors.

The choice of a Cobb-Douglas specification is based on two considerations. First, the specification has proved acceptable in previous studies of dairy farm production (Dawson and Lingard 1982), and especially in studies of farm production (Hoch 1976). Second, as explained below, the Cobb-Douglas function has a measure of the average marginal product of the jth variable factor which is particularly amenable to statistical analysis.

The average marginal product of the jth variable factor (Z_j) can be estimated by the product of the estimated output elasticity of the jth factor (β_j) and the geometric mean of the average products of the jth factor in the sample:

$$\left(Z_j = \beta_j \prod_{i=1}^{N} \prod_{t=1}^{T} Y_{it}/X_{itj}\right)^{1/NT} \tag{2}$$

where the available sample is for $t = 1, \ldots, T$ periods ($T > 2$) on each of $i = 1, \ldots, N$ firms.

This measure of the average marginal product of a variable factor was used by Mundlak (1961), Hoch (1962) and Dawson and Lingard (1982). In related work, one of the present authors (Alaouze 1985) has obtained some statistical results for Z_j. In particular, he shows that in large samples, and assuming that firms are risk neutral, Z_j can be used to construct a confidence interval for the geometric mean of the ratio of the shadow price of a variable factor to the price of output when the factor is rationed. These results are used to calculate a preliminary confidence interval for the geometric mean of the ratio of the shadow price of water to the price of butterfat for farms in the sample. An estimate of the sample size required to halve the preliminary interval is also obtained.

The remainder of the paper is in three parts. The following section contains a statistical analysis of the data from the pilot survey in which the performance of the Cobb-Douglas specification for the production function and the statistical assumptions associated with the usual analysis of covariance specification for farm production models are evaluated. Tests for the existence of strata (high salt and low salt) in the production functions of farms in the sample are also performed. In the second section a preliminary confidence interval for the geometric mean of the ratio of the shadow price of water to the price of butterfat for firms in the sample is calculated. The conclusions of the study are summarised in the final section of the paper.

Statistical Analysis of the Pilot Survey

Preliminary discussion

The estimation of agricultural production functions is complicated by the presence of unobserved (and possibly unmeasurable) factors which affect production. Examples of such factors are the level of management (Mundlak 1961), the level of technical efficiency (Hoch 1962) and soil quality (Mundlak 1961; Chamberlain 1982). The econometric problems arise because these factors are correlated with the observed quantities of inputs so that their omission from the econometric specification results in the estimates of the coefficients of the included variables being biased and inconsistent.

The application of the analysis of covariance estimator to pooled cross sectional and time series data was suggested as a solution to this latent variable problem by Mundlak (1961) and independently by Hoch (1962). Assuming the Cobb-Douglas specification is appropriate, this approach involves regressing the logarithm of output on the logarithm of each input and a set of firm-specific dummy variables. The estimated vector of slope coefficients (β) is equivalent to the analysis of covariance estimate of this parameter vector. Embodied in this approach is the assumption that the unobserved variables affect only the constant of the production function and not the coefficients of the included variables.

Most of the dairy farms in the Campaspe Irrigation District are to some extent salt affected, with some farms severely affected. This raises the question of whether the parameters of the production function (excluding the constant) can reasonably be assumed to be constant across all farms as is usual in the analysis of covariance treatment of farm production data (Dawson and Lingard 1982). In order to obtain empirical evidence on this question, 48 dairy farms in the Campaspe Irrigation District were classified into high salt and low salt strata and data were obtained from a random sample of farms from each stratum. Farms were placed in the high salt stratum if they satisfied the following three criteria:

(a) salinity levels of 520 E. C. or greater in the subsoil (90 to 120cm depth);[1]
(b) a depth to water table of two metres or less; and
(c) areas of poor pasture growth which could be observed on an aerial photograph which was printed in colour to scale of 1:25000.

[1] E.C. is the abbreviation for a unit of electrical conductivity which is measured as microsiemens per centimetre.

These criteria resulted in 10 farms being placed in the high salt stratum and 38 in the low salt stratum. After classification, the high salt farms were subjected to inspection in the field as a check on the veracity of the classification. The field inspections supported the original classification. Finally, a random sample of seven farms was drawn from each stratum and production data were collected from all but one of the sampled farms for a period of four years beginning with the 1979-80 financial year.

The null hypothesis that the vector of production function coefficients of the farms in the low salt group is equal to the vector of production function coefficients of the farms in the high salt group was tested using the usual F statistic calculated from the sum of squared residuals from the least squares fit of the constrained (pooled) regression and the sum of squared residuals from the unconstrained regression. Since the pooled model is not specified initially as the underlying model from which the sample is drawn and the outcome of the F test will be taken into account in specifying the production model applicable to the farms in the Campaspe Irrigation District, a regression strategy is being employed and the resulting estimator is a pre-test estimator.

Regression strategies are discussed by Theil (1971, pp.603-6), a concise discussion of the pre-test estimator may be found in Malinvaud (1980, pp.337-8) and a complete exposition of the pre-testing problem and the statistical properties of the pre-test estimator may be found in the monograph by Judge and Bock (1978). The statistical properties of the pre-test estimator are complicated, even if the restrictions implied by the null hypothesis are correct. If the restrictions are correct, the pre-test estimator is unbiased but its covariance matrix depends on the covariance matrix of the unconstrained estimator and the probability of accepting the null hypothesis (Judge and Bock 1978, pp.101-2). Malinvaud (1980, p.338) notes that the covariance matrix of the unconstrained estimator and the covariance matrix of the constrained estimator both underestimate the covariance matrix of the pre-test estimator. Theil (1971, pp.603-6) advises that given the state of the art, the most sensible procedure is to interpret confidence intervals and significance limits liberally when confidence intervals and test statistics are computed from the final regression of a regression strategy. That is, a 95 per cent confidence coefficient may actually be an 80 per cent confidence coefficient and a 1 per cent significance level may actually be a 10 per cent level.

Given the complications involved in pre-testing, it is hoped that the empirical results of this section will aid other researchers at the specification stage of their analysis.

Description of the sample

The survey area was restricted to the Rural Finance Settlement which is that area of the Campaspe Irrigation District west of the Northern Highway near the town of Rochester. All these farms were settled with very similar sets of resources, namely, about 40 hectares of land with a water right of approximately 160 megalitres. Those farms in the south of

the settlement were occupied by the current owners in 1970 and those in the north in 1976.

All farms in the high salt stratum are in the north of the settlement and therefore had been operated for only four years at the start of the survey. By contrast, five of the seven farms in the low salt group had been operated for ten years.

Subsequent to occupancy, some farms in both groups acquired more land by purchasing a neighbouring farm. Farms in the low salt group acquired on average a greater amount of additional land and water than farms in the high salt group, hence the scale of operation of the low salt group is higher than that of the high salt group. This is probably due to the longer period of operation of the low salt farms.

Summary statistics of some economic and physical characteristics of these farms are presented in Table 1. In the last three years, butterfat production expressed on a per hectare and per cow basis was higher for the high salt group than for the low salt group. Thus, the high salt farms appear to be farmed more intensively than the low salt farms. Another interesting feature of the sample is that by the end of the 1982-83 season, all but two of the farms in the sample were using bore water in addition to supplies from the Commission.

Statistical specification

The empirical work is based on the following statistical model:

$$(3) \quad \ln Y_{it} = \beta_{0i} + \sum_{j=1}^{7} \beta_j \ln X_{itj} + \beta_8 X_{it8} + u_{it} \qquad i = 1, \ldots, N;\ t = 1, \ldots, T$$

where Y_{it} = butterfat production by farm i in period t (in kilograms).
X_{it1} = amount of irrigation water used by farm i in year t (in megalitres).
X_{it2} = area (in effective irrigated hectares) of farm i in year t.
X_{it3} = number of milking cows on farm i in year t.
X_{it4} = amount of labour used (in adult weeks) on farm i in year t.
X_{it5} = amount spent on feed on farm i in year t (in 1981-82 dollars, excluding water and fuel costs).
X_{it6} = amount spent on other variable costs (in 1981-82 dollars) on farm i in year t.
X_{it7} = rainfall in mm at Rochester in year t.
X_{it8} = dummy variable which takes the value 1 if farm i has a bore in year t and zero otherwise.
u_{it} = a disturbance term.

An account of the derivation and sources of these data may be found in the Appendix.

It is usual in applied work to specify the distribution of the disturbance term in equation (3) conditional on the values taken by the firm effects (β_{0i}) and the explanatory variables (X_{itj}) in the sample (Mundlak 1978). It is assumed that u_{it} is a normally distributed independent random variable with mean zero and variance σ^2 which is independent of the firm effects and the explanatory variables.

TABLE 1

Summary Statistics Describing the Sample

Year	Low salt farms 1979-80	1980-81	1981-82	1982-83	High salt farms 1979-80	1980-81	1981-82	1982-83
Number of farms	7	7	6	6	7	7	7	7
Average area (ha)[a]	43.3	50.1	59.0	67.0	36.0	40.1	40.1	40.7
Average cow numbers	107.4	114.6	127.8	131.8	80.4	85	85.3	84.6
Average labour (weeks)	65.3	68.0	87.7	88.5	76.7	83.3	85.4	91.3
Average feed costs (1981-82 dollars)[b]	9612.3	11130.9	14610.3	12428.0	7448.9	8601.0	11411.3	12006.4
Average other variable costs (1981-82 dollars)	22699.9	26841.3	29937.0	33757.0	18634.3	19911.3	21422.4	24834.4
Average volume of irrigation water (ML)	425.1	540.3	630.0	482.7	386.9	432.3	438.7	399.3
Number of farms with bores	2	2	3	5	2	2	2	6
Average number of years in operation	8.3	9.3	10.0	11	4	5	6	7
Average butterfat production (kg)	18722.7	19963.6	24052.7	23239.8	13841.3	16370.3	16871.7	17233.3
Average butterfat production per ha	432.4	398.5	407.7	346.9	384.5	408.2	420.7	423.4
Average butterfat production per cow	174.3	174.2	188.2	176.3	172.2	192.6	197.8	203.7

[a] Area is measured in 'effective irrigated hectares'. For details see the Appendix.
[b] Excluding fuel and water costs.

The applied work is based on the assumption that the general specification (3) applies to the samples from the high salt and low salt strata, but that the slope coefficients of (3) and the variance of the error term of (3) are not necessarily equal across strata. Indeed, one of the objectives of the analysis is to obtain empirical evidence on the question of whether the data from each stratum can be pooled.

The model (3) was fitted to the sample of low salt farms, the sample of high salt farms and the pooled sample, and the following F tests were performed for each stratum:

(a) A test of the significance of the regression; this is a test of whether the explanatory variables other than the farm dummies belong in the relationship.

(b) A test of whether the analysis of covariance specification is appropriate; this is a test of whether the coefficients of the farm specific dummy variables are equal.

Tests were also performed as to whether there was a significant difference in the variance of the disturbance term of (3) between the strata, and whether the slope coefficients of each stratum were equal. Finally, a Lagrange multiplier test was used to test the null hypothesis that the error term in (3) was normally distributed.

Empirical results

The ordinary least squares estimates of the parameters of (3) for each stratum and for the pooled sample are reported in Table 2. Overall, very few of the estimated coefficients in the regressions for each stratum are significant. In the regression results for the high salt stratum, only the coefficient of rainfall is significant, and in the results for the low salt stratum, only the cow number variable is significant. The lack of significance of most of the slope coefficients is probably due to the small sample size in each stratum. The coefficient of determination (R^2) for the low salt stratum regression is 0.98 and for the high salt stratum is 0.96. These results indicate that the specified model fits the data well.[2] The Lagrange multiplier statistic for the test of the null hypothesis that the errors of (3) are normally distributed has asymptotically a chi-square distribution with two degrees of freedom.[3] The critical value of this distribution for a test of size 5 per cent is 5.99, so that the null hypothesis that the errors of (3) are normally distributed is not rejected by the data from both strata. This provides empirical support for the specified statistical model.

[2] The usual R^2 statistic calculated from the residuals of the regression model with firm specific dummy variables can be interpreted in the usual way, that is, as measuring the proportion of the variation in the dependent variable (about its mean) explained by the fitted regression function. A proof of this is available from the authors upon request.

[3] This test statistic is discussed in Bera and Jarque (1981).

TABLE 2

Regression Results for the Sample of High Salt Farms, Low Salt Farms and the Pooled Sample[a]

Farm dummies							Water	Area	Cow no.	Labour	Feed	Other variable costs	Rainfall	Bore dummy
							High salt farms							
D11	D12	D13	D14	D15	D16	D17	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
6.17	6.16	6.42	6.28	6.29	6.53	6.45	−0.064	0.490	0.839	0.069	0.096	−0.183	−0.191	−0.018
(2.16)	(2.10)	(2.23)	(2.13)	(2.10)	(2.16)	(2.14)	(0.121)	(0.257)	(0.515)	(0.132)	(0.077)	(0.132)	(0.093)	(0.055)
							$n=28$, $SSR=0.0442$, $R^2=0.96$, $\hat{\sigma}=0.058$, $LM=1.11$							
							Low salt farms							
D21	D22	D23	D24	D25	D26	D27	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
5.79	5.75	5.60	5.65	5.75	5.58	5.87	0.154	−0.136	0.646	0.005	0.05	0.114	0.155	−0.040
(1.75)	(1.70)	(1.71)	(1.71)	(1.70)	(1.67)	(1.75)	(0.102)	(0.150)	(0.213)	(0.138)	(0.073)	(0.116)	(0.146)	(0.051)
							$n=26$, $SSR=0.03576$, $R^2=0.98$, $\hat{\sigma}=0.057$, $LM=1.57$							
							Pooled sample							
D11	D12	D13	D14	D15	D16	D17	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
6.64	6.48	6.68	6.48	6.76	6.75	6.67	0.136	−0.069	0.788	−0.010	0.062	0.033	−0.205	−0.048
(0.87)	(0.85)	(0.88)	(0.87)	(0.88)	(0.88)	(0.87)	(0.071)	(0.101)	(0.171)	(0.095)	(0.046)	(0.088)	(0.068)	(0.045)
							$n=54$, $SSR=0.123702$, $R^2=0.97$, $\hat{\sigma}=0.062$, $LM=1.25$							
D21	D22	D23	D24	D25	D26	D27								
6.71	6.70	6.57	6.51	6.71	6.55	6.77								
(0.91)	(0.88)	(0.88)	(0.88)	(0.89)	(0.87)	(0.91)								

[a] n is the sample size, SSR is the sum of squared residuals from regression, R^2 is the coefficient of determination, $\hat{\sigma}$ is the standard error of estimate, LM is a Lagrange multiplier statistic for testing the normality of the regression error term, and estimated standard errors appear in parentheses under the coefficient estimates.

Turning to the F tests reported in Table 3, it is evident that the regression is significant in both the low salt and the high salt strata. The test of the null hypothesis that farm dummies can be pooled is rejected at the 5 per cent level for the data from the high salt farms and is only just under the critical value for rejection (3.09) for the low salt farms. This provides empirical support for the analysis of covariance specification.

TABLE 3

Results of F Tests Within Strata

Test	Stratum: Low salt	Stratum: High salt
Significance of regression	$F(8,11) = 11.79$*	$F(8,13) = 8.58$*
Analysis of covariance	$F(6,11) = 3.02$	$F(6,13) = 7.03$*

* Indicates significance at the 5 per cent level.

The F statistics associated with the test of the null hypothesis that the slope coefficients of (3) are equal across strata, and the test of the null hypothesis that the variance of the error term of (3) is equal across strata are reported in Table 4. Neither null hypothesis is rejected so there is statistical evidence supporting the pooling of the two strata.

TABLE 4

Results of F Tests Concerning Whether Strata Can Be Pooled

Test	Statistic
Pooling of slope coefficients	$F(8,24) = 1.64$
Equal variances	$F(13,11) = 1.05$

The empirical results of this section support the pooling of the two strata and the conclusion that variations in the soil quality of irrigated dairy farms in the Campaspe Irrigation District can be adequately modelled by the usual analysis of covariance specification. Since we have been led to the specification of the pooled analysis of covariance model by preliminary testing, the ordinary least squares standard errors reported in Table 2 for the estimated parameters of the pooled regression should be regarded as having a downward bias.

A Preliminary Confidence Interval for the Average Ratio of the Shadow Price of Water to the Price of Butterfat

In this section some results derived in Alaouze (1985) are used to calculate a preliminary confidence interval for the geometric mean of the ratio of the shadow price of water to the price of butterfat for the farms in the pilot survey. The results are derived under the assumptions that the farmers in the sample choose the levels of inputs which maximise the mathematical expectation of profits, that factor and output prices are known with certainty and that one factor, say the kth, is rationed in

period t. Under these assumptions, and the statistical model and assumptions for estimating the parameters of (3) described earlier, it can be shown that the statistic $Z_j\theta$ (where $\theta = \exp\{\sigma^2(1-1/NT)/2\}$) has, as the number of farms increases indefinitely ($N \to \infty$), and conditional on the level of inputs and fixed factors used by the firms in the sample, an asymptotic normal distribution:

$$(4) \qquad \underset{(N\to\infty)}{(NT)^{1/2}(\theta Z_j - \tilde{P}_j/\tilde{P})} \underset{\sim}{D} N(0, \bar{\theta}^2 V_j)$$

where: $\bar{\theta} = \exp\{\sigma^2/_2\}$

$$\tilde{P}_j = \left(\prod_{i=1}^{N} \prod_{t=1}^{T} P_{itj}\right)^{1/NT} \qquad j = 1, \ldots, k-1$$

is the geometric mean of the price in period t for firm i of the jth of the $(k-1)$ factors which are not rationed, and

$$\tilde{P}_k = \left(\prod_{i=1}^{N} \prod_{t=1}^{T} (P_{itk} + \lambda_{itk})\right)^{1/NT}$$

is the geometric mean of the shadow price of the rationed factor for firm i in period t. (Note that $\lambda_{itk} > 0$ is the Lagrange multiplier associated with the restriction that the kth factor is rationed in the firm's optimisation problem.)

$$\tilde{P} = \left(\prod_{i=1}^{N} \prod_{t=1}^{T} P_{it}\right)^{1/NT}$$

is the geometric mean of the price of output for firm i in period t, V_j is the variance of the asymptotic distribution of Z_j, and $N(\mu,\sigma^2)$ is the normal distribution with mean μ and variance σ^2.

In order for (4) to be operational, consistent estimates of θ, $(\hat{\theta})$ and V_j, $(\hat{V}_j)$ are required. It can be shown that the following statistics:

$$\hat{\theta} = \exp\{\sigma^2(1-1/NT)/2\}$$

and

$$\hat{V} = \hat{\sigma}^2 Z_j^2 + NT\, \hat{V}(\hat{\beta}_j)\, Z_j^2/\hat{\beta}_j^2$$

where $\hat{\sigma}^2$ is the estimate of σ^2 obtained in the usual way from the residuals of the fitted regression, and $\hat{\beta}_j$ is the analysis of covariance estimator of the jth slope coefficient in the regression function of the transformed Cobb-Douglas function, are consistent estimators of θ and V_j.

Thus, in large samples, the interval:

$$(5) \qquad \hat{\theta} Z_j \pm \phi(1-\alpha/2)[(1/NT)\hat{\theta}^2 \hat{V}_j]^{1/2} \qquad j = 1, \ldots, k$$

where $\phi(1-\alpha/2)$ is the $(1-\alpha/2) \times 100$ percentile of the standard normal distribution, is an approximate $(1-\alpha) \times 100$ per cent confidence interval for the geometric mean of the ratio of the price ratio of firms in the sample.

The interval (5) is actually a large sample confidence interval for the geometric mean of the expected marginal product of each factor for firms in the sample. Thus, when firms are risk averse, the interval (5) can

be interpreted as estimating the geometric mean of the ratio of the implicit shadow price of the factor to the price of output.

In the case of the dairy farms in the pilot survey, the farmers know the relevant butterfat and water prices which are applicable during the production period. In applying the results described above, the relevant statistics obtained for the pooled regression are used, so that the results should be regarded as approximate. Letting β_1 denote the point elasticity of output with respect to the use of irrigation water, then for this sample:

$NT-2=54$ (where $N=14$ and $T=4$)
$\hat{\beta}_1=0.1361$
$\hat{V}(\hat{\beta}_1)=0.0050$
$\sigma^2=0.0039$
$Z_1=5.4952$ (kg butterfat per ML water)
$\hat{\theta}=1.0019$
$\tilde{P}_1/\tilde{P}=5.89/3.33=1.7688$ (kg of butterfat per ML water)

These estimates yield an estimate of the variance of the asymptotic distribution of Z_1 of 440.16 and a 95 per cent confidence interval for the geometric mean of the ratio of the shadow price of water to the price of butterfat in the sample of -0.1260 to 11.1164.

This interval is rather wide compared to the point estimate of Z_1 (5.4952) and also includes negative values. The geometric mean of the actual price ratio (1.7688) is at the lower end of the interval indicating that the price ratio could be increased substantially and still lie in the interval. A sevenfold increase in the price ratio would however lie outside the interval.

Assuming that the original sample is random, the approximate size of a random sample that would halve the width of the above interval can be found by solving:

$$(1/4N)^{1/2}=\tfrac{1}{2}(1/54)^{1/2}$$

for N.[4] This calculation indicates that four years of data from a random sample of approximately 54 farms are required to obtain a confidence interval which is half the width of the one reported above.

Summary and Conclusions

The empirical results indicate that model (3) fits the data well, and that the analysis of covariance specification with the assumption of normality in the errors is supported by two independent samples. The null hypothesis that the slope coefficients of (3) are equal across strata was not rejected, nor was the null hypothesis that the variance of the error term of (3) is equal in both strata. Thus, there is statistical evidence supporting the pooling of the two strata.

This analysis has emphasised the importance of using the analysis of covariance estimator with combined cross sectional and time series data. It has also indicated the value of pilot surveys at the specification stage of analyses using production functions. The results are reassuring because they support the conclusion that variations in the soil quality of irrigated dairy farms in the Campaspe Irrigation District can be adequately

[4] Since the data collected in the pilot survey are not a random sample, this exercise should be regarded as approximate.

modelled by the usual analysis of covariance specification; that is, different degrees of salting affect only the intercept values.

This analysis has shown the need to consider confidence intervals when interpreting point estimates of marginal productivities. The geometric mean of the ratio of the water price to the price of butterfat of the farms in the pilot survey is at the low end of the calculated confidence interval for the geometric mean of the ratio of the shadow price of water to the price of butterfat for these farms. Since the interval is wide and the geometric mean of the actual price ratio is fairly stable, this can be taken as evidence supporting the hypothesis that rationed irrigation water is worth more to these farms than the price paid. A sample of four years of observations on approximately 54 farms is required to halve the reported confidence interval.

Detailed analysis of the efficiency of water use on these farms and its implications for water policy must await an appropriate 'large-sample' study. Nevertheless, the statistical evidence from this pilot survey which suggests that irrigation water is worth more to these farms than the price charged by the Rural Water Commission is augmented by the fact that the farms are high users of water, including bore water. Officers of the Commission have estimated that the fuel cost for pumping from the bores is about $20 per megalitre. When interest and depreciation costs are added the average cost would be about $30 per megalitre (Centre of Policy Studies 1983, Appendix p.L2). These pieces of evidence, when taken together, suggest that farmers in the Campaspe Irrigation District, irrespective of the degree of soil salting on their farms, are likely to be able to pay higher prices for their current supplies of water. Conversely, they are likely to be willing to acquire more water (with the same security of supply) at the current price charged by the Commission. The issue of transferable entitlements to Victoria's irrigation water is under close scrutiny (ACIL Australia Pty Ltd 1984). Again, these pieces of evidence suggest that dairy farmers in the Campaspe Irrigation District are likely to be buyers of extra water entitlements if such a scheme were implemented.

APPENDIX

The questionnaire designed for the study was based on the questionnaire used by the Victorian Department of Agriculture for the Dairy Farm Management Study. Technical and financial data for the 1979-80 and 1980-81 financial years were obtained from the sampled farms in early 1982. Data for the two subsequent financial years were obtained during 1983. Most of the financial data were derived from farmers' tax returns, factory statements, cash books and cheque butts. Technical information was obtained by questioning the farmers and from their records.

Butterfat production (Y) is the total production of butterfat (kg) of each farm in each year. These data were obtained from the farmers' factory statements.

Irrigation water (X_1) is the amount of applied water measured in megalitres. Applied water is a sum of water purchased from the Rural Water Commission and water pumped from any bores on the farm. The quantity of bore water was estimated by the farmers from their records.

Area (X_2) of the farm is measured in terms of 'effective irrigated hectares'. An effective irrigated hectare is a measure of farm area used in the Dairy Farm Management Study to account for the differences in production of irrigated permanent pastures, irrigated annual pastures and dry land pastures. The areas of these various types of pasture are combined according to the formula: effective irrigated hectares = irrigated permanent pasture (ha) + 0.5 (irrigated annual pasture (ha)) + 0.1 (dryland pasture (ha)).

Milking cows (X_3) is the maximum number of cows milked on each farm during each year.

Labour (X_4) used on the farm is measured in adult weeks. The age of workers and the number of weeks supplied by each worker were obtained from the farm operator. The conversion factors used in the Dairy Farm Management Study were used to convert actual weeks to adult weeks, namely:

Age	21	20	19	18	17	16
Per cent of adult weeks	100	90	80	70	60	55

Feed costs (X_5) is the amount (expressed in 1981-82 dollars) spent each year on providing feed to cows. Included in this variable were the costs of fertiliser, purchased hay and grain, agistment, and weed and pest control. Expenditure on water, and fuel and oil were not included in this cost category because water use enters our specification separately and it was not possible to estimate the amount of fuel and oil used solely for feed production.

Other variable costs (X_6) is the amount (expressed in 1981-82 dollars) spent on items such as electricity, dairy supplies, artificial breeding, herd testing, animal health, calf rearing, and repairs and maintenance to plant and equipment.

Rainfall (X_7) is the annual rainfall (mm) for each year recorded at Rochester. These observations were obtained from the Bureau of Meteorology.

Bores (X_8). During the period for which data were acquired, an increasing number of the farmers sank bores to deep leads to obtain additional water (see Table 1). This dummy variable takes the value 1 if a farm had a bore in a given year and zero otherwise.

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