

USING INPUT DEMAND AND PRODUCTION FUNCTION MODELS TO ASSESS THE NET BENEFITS OF DAIRY HERD IMPROVEMENT

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Two methods of evaluating the net social benefits of the dairy herd-improvement scheme operated by the New South Wales Department of Agriculture are described. The first involves derivation of an input demand function for the herd-recording aspect of the scheme and use of this function to estimate the economic surplus (net of both private and public costs) provided by the service. The second approach involves deriving a production function for milk from which it is possible to estimate the contribution herd-recording and artificial breeding have made to increasing milk yields per cow. Social benefits are shown to have been less than social costs for herd-recording, however dairy farmers have made net private gains. The herd-recording scheme has contained a regressive subsidy element. The production function approach shows that artificial breeding and herd-recording were profitable complements in production.

Introduction

Dairy herd-improvement in New South Wales involves a combination of artificial breeding and herd-recording. Herd-recording of dairy cattle has been carried out by the N.S.W. Department of Agriculture since 1924-25, and artificial breeding since 1952. Herd-recording provides the farmer with information which may be used in culling and replacement policies, in the proving of bulls, in checking on milking efficiency, in decisions about when to terminate lactation, and in feeding programmes. Artificial breeding aims to make semen from superior bulls available to commercial dairy farmers so that they can improve the productivity of their herds.

In N.S.W. in 1970-71 there were 91,000 cows in the Group Herd-recording Scheme, which largely covers commercial herds, and a further 12,700 in the Official Scheme, which includes only registered herds. Production from these cows represented 26 per cent of total N.S.W. dairy production in that year. The average fee charged to farmers in the Group Scheme in 1970-71 was \$1.84 per cow. For the Official Scheme the charge was \$3.67. Farmers in the Official Scheme are provided with much more detailed information than those in the Group Scheme which explains the higher charge. The total public outlay on

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the dairy herd-recording schemes in N.S.W. for 1970-71 was \$630,000. Farmers paid \$214,000 of this in fees, the Commonwealth Extension Services Grant contributed \$71,000, and the remaining \$345,000 was financed from N.S.W. Consolidated Revenue.

A multi-country study has shown that, as one would expect, there is a greater increase in the production of cows in recorded herds than from cows in non-recorded herds [10]. Most of the increased production appears to be gained in the first four to six years of recording. Bradbury [1] in 1957 and Walsh [15] in 1969-70 estimated the annual net private benefit from herd-recording in Victoria to be in the range of \$5 to \$6 per cow. These three studies [1, 10 and 15] assumed that all the difference between the production in recorded and non-recorded cows could be attributed to herd-recording. No allowance was made for extra costs or the productive contribution of other inputs which may have also increased (or decreased) during the period examined. Indeed, increased production per cow is not the only or necessarily the best measure of the benefits accruing to dairy herd-recording. In many instances increased stocking rates reduce the significance of per cow comparisons. Also, to the extent that better managers adopt herd-recording, some of the benefits attributed to herd-recording may rightfully be due to managerial ability.

Noble and Curtin [10] also noted the absence of any evaluation of the net benefits of herd-recording in a macro-sense. However, studies have been made of the expected gains from genetic improvements resulting from national breeding programmes in dairy and beef herds by Hill [6], Hinks [7] and others in Europe. Internal rates of return in excess of 20 per cent are reported.

In the present study two methods of measuring the net social benefits of herd-recording are described. The first is an input demand model where the area between the demand curve for herd-recording and the price charged is used as a measure of the economic surplus accruing to society from the scheme. The approach used here is similar to that used by Duncan [3] in measuring the welfare effects of new pasture technology in the Australian woolgrowing industry.

The second method is used to evaluate both herd-recording and artificial breeding. A production function for milk is employed where the level of use of herd-recording and artificial breeding are included as explanatory variables, along with the levels of other productive inputs such as land, labour, capital, etc.

The production function model allows evaluation of the individual and complementary effects of herd-recording and artificial breeding, whereas the input demand model does not. Also, data on the demand for artificial breeding were not available to use in an input demand framework. Use of the input demand model was the only option in the case of Official herd-recording, as the Bureau of Agricultural Economics Dairy Industry Survey data which were utilized in the production function analysis do not include registered herds. Having the two sources of data for Group herd-recording affords an opportunity to compare the results of two alternative methods of answering the same question.

The Input Demand Model

The process of herd-recording is considered as input X_1 in the pro-

duction function represented as,

$$(1) \quad Q = f(X_1, X_2, \dots, X_n),$$

where Q = dairy output, and $X_2 \dots X_n$ are the other productive inputs.

The derived demand for herd-recording can be represented as follows:

$$(2) \quad X_1 = g(r_1, r_2, \dots, r_n, P \dots),$$

where r_1 is the fee for herd-recording, $r_2 \dots r_n$ are input prices, and P is the product price.

In the model the input demand function for herd-recording is assumed to be fixed and known over the period being examined.¹ The input demand curve is depicted in Figure 1. If r_1^o is the fee charged to farmers for herd-recording, r_1' the fee generating zero demand and X_1^o is the number of cows being recorded, then the area ABC in Figure 1 is the estimate of economic surplus, or the net private benefit from herd-recording.² Net social benefits are calculated by subtracting government costs from ABC.³

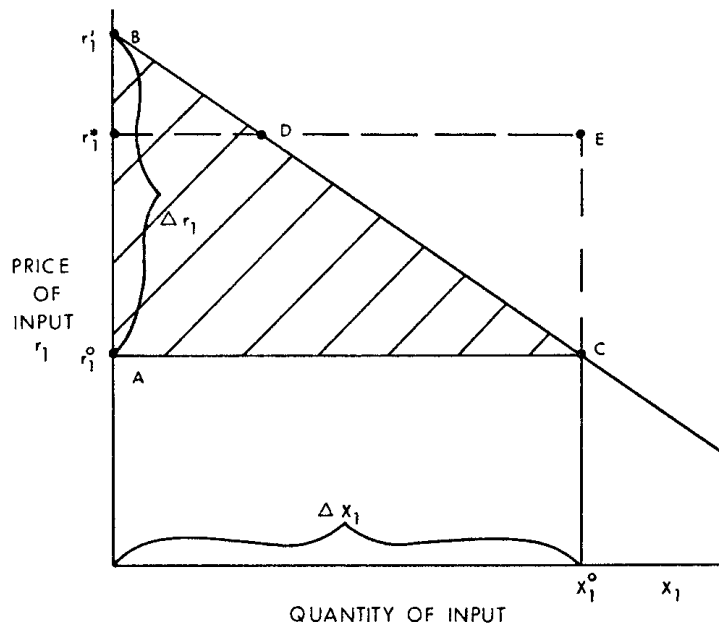


FIGURE 1

¹ There are no technological shift parameters, as in Duncan's [3] model.

² Wisecarver [16] has recently shown that as long as we are dealing with derived input demand curves the correct welfare measure of a tax on an input is the relevant area between the input's demand and supply schedules (ABC in our case). He shows that Schmalensee [13] is incorrect in concluding that this input-market measure overestimates the true social loss by a term which is a pure substitution-in-production effect. Wisecarver [16] proves that this 'substitution' component is also a true social loss which must be included.

³ This is separate to the question of the social costs involved in the provision of the service at less than the full market cost. This latter social loss is measured by the area within triangle DEC in Figure 1.

Now,

$$(3) \quad ABC = W = 1/2 X_1^0 \Delta r_1,$$

where $\Delta r_1 = r'_1 - r^0_1$.

To calculate W requires estimation of Δr_1 , the increment in the fee for herd-recording required to generate zero demand for it. To do this, natural logarithmic input demand equations were fitted to time series data available from records in the Division of Dairying of the N.S.W. Department of Agriculture. Data were available on the number of cattle recorded, fees charged, cost to the government, and yields of milk and butterfat from recorded cows. Complete information on the Official Scheme was available from 1956/57 to 1970/71, and on the Group Scheme from 1946/47 to 1970/71.

The form of the input demand models is:

$$(4) \quad \ln X_1 = a + b \ln(C/PR) + c \ln(PP/PR) + d \ln(K) + e(R)$$

where X_1 is the number of cows recorded in N.S.W., C is the herd-recording fee per cow, PR is the B.A.E. Index of Prices Received for dairy produce, PP is the B.A.E. Index for Prices Paid for all farm input items in N.S.W., K is a capacity variable (inserted to deal with the problem that the service is government supplied and demand is hence limited, to some extent, by the resources allocated to herd-recording by the Government) and R is a rainfall dummy, taking the value 1 in drought years and zero in others, as defined by Gibbs and Maher [4]. The C/PR variables were all set up in the Fisher fixed-weight lag form shown in equation (5):

$$(5) \quad F(C/PR)_t = 1/2(C/PR)_t + 1/3(C/PR)_{t-1} + 1/6(C/PR)_{t-2}.$$

The Production Function Model

A Cobb-Douglas production function of the following form is assumed:

$$(6) \quad Q = \exp \left[(A + \sum_i \beta_i Y_i + \sum_j \gamma_j R_j) + \sum_k \delta_k H_k + \sum_l \xi_l B_l + \sum_m \theta_m (HB)_m \right] X_2 \dots X_n,$$

where

Q = milk output per cow (litres).

A = constant term.

Y_i = Two year dummy variables. Each takes the value zero in 1967-68. The 1968-69 dummy takes the value one in that year and zero in 1969-70. The 1969-70 dummy takes the value one in that year and zero in 1968-69.

R_j = Four region dummy variables. Each takes the value zero for the Richmond-Tweed-Clarence. The Hastings-Hunter takes the value one when data derive from that region and zero for all other data. The same applies respectively for the Sydney-Illawarra, South Coast and Murrumbidgee-Murray regions.

H_k = Five region by herd-recording dummy interaction variables. Each of these takes the value one when data derive from that particular region and the farm herd-records. They take the value zero otherwise.

B_e = Five region by artificial breeding dummy interaction

- variables. Each of these takes the value one when data derive from that particular region and the farm artificially breeds. They take the value zero otherwise.
- $(HB)_m$ = Five region by herd-recording by artificial breeding dummy interaction variables. Each of these takes the value one when data derive from that particular region and the farm both herd-records and artificially breeds. They take the value zero otherwise.
- X_2, \dots, X_n = The level of other continuous inputs ($n = 2, 3, \dots, 12$) consisting of dairy labour (dollars), number of cows, land value (1967 dollars), capital excluding land and cows (dollars), improved pasture (ha), irrigated land (ha), cereals fed (m^3), hay and silage fed (tonnes), fruit and vegetables fed (m^3), milk products fed (kl) and feeds and concentrates fed (kg).

The Greek symbols refer to the parameters to be estimated.

The data consisted of observations on the above variables for 250 farms over the three years 1967-68 to 1969-70 from the Bureau of Agricultural Economics Dairy Industry Survey in N.S.W. The analysis is restricted to the Group Herd-recording Scheme as no registered herds are included in the B.A.E. survey.

The contribution that herd-recording (I_{H_k}) and artificial breeding (I_{B_1}) make to milk production per cow on farms in the survey is estimated by taking the partial differential of Q in equation (6) with respect to both H and B by regions.⁴ That is:

$$(7) \quad I_{H_k} = Q_k^* (\delta_k + \theta_m B_m), \text{ and}$$

$$(8) \quad I_{B_1} = Q_1^* (\zeta_1 + \theta_m H_m),$$

where the Q^* are base yields without improvement.

The aggregate value to society from the provision of herd-recording can be estimated using information obtained from the I_{H_k} calculations in equation (7) and the model developed by Peterson [12]. This is illustrated in Fig. 2 which is adapted from Parish [11, p. 168]. At the margin, additional milk produced as a result of herd-recording has a real value equal to the price P_e , which is the export price received for manufactured dairy products. At the home consumption price P_h , domestic consumption of dairy products is Q_h measured from the domestic demand curve $D_h D_h'$. The equalized price schedule is represented by $D_h P_p$ which rises to $P_t P_t'$ when the current Commonwealth bounty is added. Total present production of dairy products is represented by the quantity Q_t . The effect of herd-recording on the milk supply curve is represented as a shift from $S_2 S_2'$ to $S_1 S_1'$, allowing an increase in total production of $Q_t' Q_t$, all of which represents additions to exports ($Q_0 Q_1$).

⁴ The total differential would further involve determination of the effects that increases in the levels of H and B (i.e. from zero to one) have on the level of use of all other inputs and thence their effect on Q . It entails solution of a large number of complicated simultaneous equations requiring information on the prices and degree of substitutability for all other inputs, which was not available. Furthermore, it is likely that the estimated partial differentials themselves are positively biased in view of the positive correlation between adoption of H and B and level of management.

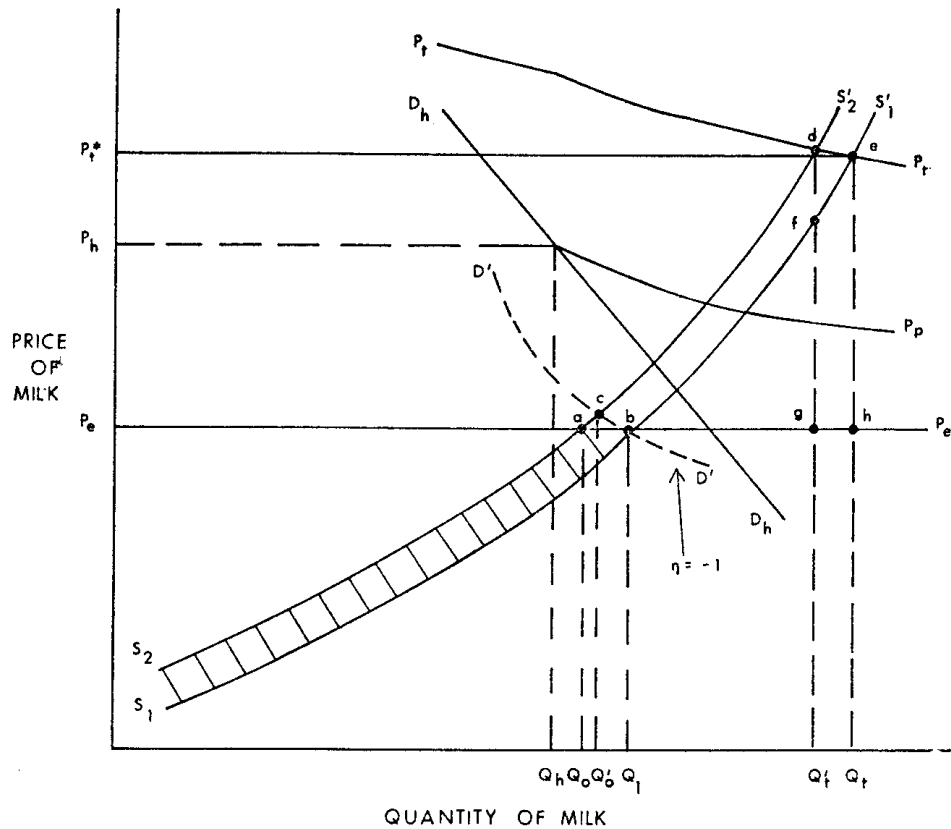


FIGURE 2

The value of the resources saved by this shift is shown by the shaded area S_2abS_1 in Figure 2. It is measured as the resource savings S_2deS_1 in producing the quantity Q_t' , minus the resource cost $gfeh$ of producing the additional output $Q_t'Q_t$. As $adfb$ approximately equals $gfeh$, we obtain the shaded area S_2abS_1 as our net saving. As Peterson [12] demonstrates, this area can be measured by the following formulae in the situation where the elasticity of product demand is infinite:

$$(9) \quad S_2abS_1 = KP_e[Q_1 - Q_0K\lambda/2],$$

where $K = Q_0'Q_1/Q_1$, or the fraction by which the supply curve shifts as a result of herd-recording,⁵ and

$\lambda =$ elasticity of supply of dairy products in Australia.

The value of K can be determined as the summation of the milk yield increments I_{HK} over all cows which were Group herd-recorded in New South Wales expressed as a fraction of Q_1 . From the shaded area S_2abS_1 is subtracted the sum of the farmers' and the government's costs of herd-recording to obtain an estimate of the net social benefits of herd-recording.

⁵ Q_0' is the pre-herd-recording intersection of D_1D_1 and S_2S_2 , where D_1D_1 is a unitary elastic demand curve. Peterson [12] does not demonstrate how $Q_0'Q_1$ is calculated. However, Q_0Q_1 is a close approximation and is used in this study for convenience.

*Empirical Analyses**Input Demand Curves for Herd-recording*

Single equation ordinary least squares regression analyses were performed on the natural logarithmic transformations of the data using equation (4). This type of model involves the constant elasticity assumption and was chosen primarily for ease of analysis. Various regressions were run using different data sets for the dependent variable such as number of recorded cows, number of herds and a split up into number of cows recorded in the milk zone and the manufacturing zone. Various data for the prices received and capacity variables were also tried. The preferred demand equations are shown in Table 1. They were chosen on the basis of the correctness of the signs and significance levels of the coefficients and for non-rejection of the hypotheses of no serial correlation using the Durbin-Watson statistic.

The elasticity of demand for the Group Scheme would appear to be approximately -0.4 while for the Official Scheme unitary elasticity is indicated. The Official Scheme could be expected to have a higher elasticity as owners of the registered herds are able to utilize the lower-priced Group Scheme, whereas commercial herds are excluded from the Official Scheme. Furthermore, it is agreed by dairy research and extension personnel that farms with low initial milk yields are more likely to derive larger increments in milk production from herd-recording than are those with high initial yields. Group herds generally have lower yields per cow than Official herds and one may therefore expect their demand for herd-recording to be less elastic.

The elasticities are comparable to the experience in Manitoba, as reported by Dairy Farmers of Canada [2, p. 82]. When fees were increased in Manitoba from \$C2.50 to \$C3.50 per cow, one-third of the members dropped out of the scheme. This results in an estimated arc elasticity of demand of -0.83 .

If the full cost (government plus private) of herd-recording were charged to farmers in 1970-71, the fees would have been \$5.31 and \$11.52 per cow for the Group and Official Schemes, compared to the actual fees of \$1.84 and \$3.67, respectively.⁶ Using -0.4 and -1.0 as the elasticities of demand for Group and Official herd-recording respectively, the estimated reduction in the number of Group cows herd-recorded if \$5.31 was charged would be approximately 69,000. If \$11.52 per cow were charged for the Official Scheme it is likely the demand would fall from the 12,000 cows recorded in 1970-71 to zero.

Production Function for Milk

The model described in equation (6) was fitted by ordinary least squares regression on the logarithmic transformation of the equation.⁷

⁶ The cost data were derived from records of the Dairying Division of the New South Wales Department of Agriculture.

⁷ Wallace and Hussain [14] have shown that the covariance estimators used in equation (6) are unbiased and asymptotically equivalent to Aitken's Generalized Least Squares estimators using known variance components in the case of weakly non-stochastic independent variables. Aitken's estimators are asymptotically superior with non-stochastic independent variables. However, covariance estimators 'clean up' specification error.

TABLE 1
Input Demand Equations for Herd-Recording^a

Equation	Dependent Variable	Constant	lnF (CG/PRD)	lnF (CG/PRM)	lnF (CO/PRP)	ln (PP/PRD) (PP/PRD)	ln (PP/PRM) (PP/PRM)	ln (PP/PRP) (PP/PRP)	ln(NHR)	RAIN	\bar{R}^2 ^b	d ^c
<i>Group Scheme:</i>												
(A)	ln(X ₀)	4.73	-0.36* (1.93) ^d			0.69** (3.01)			1.62** (7.59)	0.011 (0.19)	0.89	1.90
(B)	ln(X ₀)	5.13		-0.44** (2.76)			1.65** (3.18)		1.57** (7.70)	0.016 (0.30)	0.90	1.91
<i>Official Scheme:</i>												
(C)	ln(X ₀)	1.12			-1.00** (3.74)			2.61** (5.34)	1.86** (5.02)	-0.09 (1.11)	0.91	2.33

a *Definitions:* X₀—number of Group herd-recorded cows in N.S.W.; X₀—number of Official herd-recorded cows in N.S.W.; CG—fee for Group herd-recording per cow in index form; CO—fee for Official herd-recording in index form; PP—B.A.E. Prices paid Index for Farmers (all expenses; NHR—number of herd-recording units in N.S.W.; RAIN—dummy variable for rainfall, 1 in drought years, zero otherwise; PRD—B.A.E. Prices Received Index for Total Dairy Produce (N.S.W.); PRM—B.A.E. Prices Received Index for Human Consumption (Aust.); PRP—B.A.E. Prices Received Index for Cream Processing (Aust.); F—fixed-weight Fisher lag operator.

b Coefficient of determination corrected for degrees of freedom.

c Durbin-Watson statistic. In all three equations the hypothesis of no serial correlation is not rejected.

d t-values shown in parentheses under the coefficients with * and ** implying significance at the five and one per cent levels respectively, using one-tail tests.

TABLE 2
Dairy Farm Production Function^a

Variable Description	Units	Coefficient ^f (i.e. produc- tion elasticity)	t-value
Constant ^b	—	4.6982**	9.48
Year 1968-69 Dummy ^c	—	-0.0712**	4.48
Year 1969-70 Dummy ^c	—	0.0762**	4.76
Hastings-Hunter Region Dummy ^d (HH)	—	0.1278*	2.17
Sydney-Illawarra Region Dummy ^d (SI)	—	0.2523**	3.18
South Coast Region Dummy ^d (SC)	—	0.2298**	4.39
Murrumbidgee-Murray Region Dummy ^d (MM)	—	0.1906**	3.06
Herd Recording (H) x (RTC) ^d	—	0.2915**	5.02
Herd Recording (H) x (HH) ^d	—	0.0621	0.88
Herd Recording (H) x (SI) ^d	—	-0.1277	1.23
Herd Recording (H) x (SC) ^d	—	0.0283**	2.80
Herd Recording (H) x (MM) ^d	—	0.0722	1.21
(H) x (RTC) x Artificial Breeding (B) ^d	—	-0.1951	1.74
(H) x (HH) x Artificial Breeding (B) ^d	—	-0.0360	0.32
(H) x (SI) x Artificial Breeding (B) ^d	—	0.1406	1.16
(H) x (SC) x Artificial Breeding (B) ^d	—	0.2575	1.50
(H) x (MM) x Artificial Breeding (B) ^d	—	0.1413	1.07
(B) x (RTC) ^d	—	0.3119**	4.29
(B) x (HH) ^d	—	0.1003	1.48
(B) x (SI) ^d	—	0.0358	0.53
(B) x (SC) ^d	—	-0.2095	1.90
(B) x (MM) ^d	—	0.0449	0.49
Dairy Labour	\$	0.3147**	8.60
Number of Cows	head	-0.3268**	7.31
Total Land Value ^e	\$	0.1100**	3.85
Capital (excl. land and cows)	\$	0.0266	0.97
Improved Pasture	ha	0.0103	0.92
Irrigated Land	ha	0.0423**	5.91
Cereals Fed	m ³	0.0062	1.40
Hay and Silage Fed	tonne	0.0345**	4.21
Fruit and Veggies. Fed	m ³	0.0432	0.77
Milk Products Fed	kl	-0.0062	0.79
Feeds and Concentrates Fed	kg	0.0095*	1.81
		R ² 0.48	S.E. 0.306

^a The dependent variable is the natural logarithm of milk per cow (litres). All independent variables other than the dummies are in natural logarithms. Herd-recording (H) and artificial breeding (B) variables are in dummy (zero-one) form.

^b The constant term refers to the intercept for 1967-68 for the Richmond-Tweed-Clarence region (RTC).

^c Variable takes value 1 in year specified and zero in other year.

^d Variables take value of 1 in region specified and zero elsewhere.

^e Land was valued at constant 1967 prices.

^f ** and * beside the coefficients represent significance at the one and five per cent levels respectively, when the sign is as expected and using a one-tail test.

The preferred equation is shown in Table 2.⁸ It shows that there were

⁸ Logarithmic regressions were also run where the number of years herd-recording had been conducted on the farms was used in place of the herd-recording dummy variable. These indicated that the duration of herd-recording had a significant positive diminishing effect on yield per cow, as was expected. Logarithmic regressions with the amount spent on artificial breeding used instead of a dummy variable form also indicated a significant positive effect for artificial breeding on milk yield per cow.

correct signs on all but five of the 26 coefficients which had determinate expected signs. As a one-tail t-test is appropriate the null hypothesis of a positive value for these five coefficients was rejected in favour of the alternative hypothesis of zero.

It appears from Table 2 that the Group herd-recording scheme had the most substantial positive effect on milk yield per cow in the Richmond-Tweed-Clarence region. Very much smaller effects are indicated for the Murrumbidgee-Murray, Hastings-Hunter and South Coast regions. Artificial breeding appeared to have a substantial effect on milk yield per cow in the Richmond-Tweed-Clarence region, with much smaller effects in Hastings-Hunter, Murrumbidgee-Murray and Sydney-Illawarra regions. These differences could be because of factors such as more widespread use of proven bulls in the former region. The effect of artificial breeding was enhanced by the conduct of herd-recording on farms (and vice versa) in three of the five regions studied, namely the South Coast, Sydney-Illawarra and Murrumbidgee-Murray.

A note of caution should be made regarding the coefficients on the herd-recording and artificial breeding variables. It is likely that those farmers who engage in either or both of these activities also have above-average managerial expertise. The measured coefficients on these variables may represent upward-biased estimates of their contribution to milk yield per cow.

Estimated Value of Herd-Recording

The elasticities of demand for herd-recording (γ) of -0.4 and -1.0 for the Group and Official Schemes respectively, were employed in equation (11) to estimate Δr_1 , where

$$(10) \quad \gamma = \Delta X_1 r_1 / X_1^0 \Delta r_1,$$

As $\Delta X_1 = X_1^0$, in the situation depicted in Figure 1, we have

$$(11) \quad \Delta r_1 = r_1 / \gamma.$$

This generates the intercept Δr_1 , from tangents whose slopes vary with r_1 along the logarithmic demand curve. This of course involves some under-estimation in view of the fact that logarithmic functions are asymptotic to the vertical axis. Extrapolation beyond the range of the data is also required with its attendant errors.⁹

Table 3 contains estimates of net public benefits which have accrued to the Group herd-recording scheme since 1946-47, using the input demand model. These estimates measure the economic surplus accruing to society after allowing for the private and government costs of herd-recording. They have all been measured in 1970-71 dollars using the Consumer Price Index as the inflator. The Group Scheme has apparently involved a net loss to society of the order of \$67,000 annually while the Official Scheme has lost \$38,000.¹⁰ Total annual producers' surplus from the Group Scheme averaged \$119,000 and that from the Official

⁹ Linear input demand functions were also fitted but the extrapolation involved in estimating Δr was many times greater than for the logarithmic functions. They were discarded for this reason.

¹⁰ Furthermore, the average annual social loss from provision of the service at less than the real social resource cost (i.e. the area DEC in Figure 1, where r^*_1 is the sum of private and government costs per cow), amounted to \$78,000 in terms of 1970/71 dollars for the Group Scheme and \$38,000 for the Official Scheme.

TABLE 3
Net Social Benefits of Herd-Recording in N.S.W.^a
 (\$'000)

Year	Group Scheme		Official Scheme ^b
	Input Demand Model	Production Function Model ^c	Input Demand Model
46-47	-34	-	-
47-48	-62	-	-
48-49	-87	-	-
49-50	-78	-	-
50-52	-93	-	-
51-52	-94	-	-
52-53	-112	-	-
53-54	-31	-	-
54-55	-41	-	-
55-56	-36	-	-
56-57	-39	-	-27
57-58	-71	-	-21
58-59	-82	-	-17
59-60	-63	-	-9
60-61	-82	68	-19
61-62	-70	166	-15
62-63	-115	237	-25
63-64	-25	273	-30
64-65	-60	297	-30
65-66	-104	186	-58
66-67	-81	234	-71
67-68	-125	240	-55
68-69	47	67	-60
69-70	-36	130	-52
70-71	-106	35	-77
Average Annual	-67	175	-38

^a Net Social Benefits are the estimated gross benefits minus government and private costs, all measured in 1970/71 dollars using the Consumer Price Index as the inflator.

^b Data for the Official Scheme were not available prior to 1956/57.

^c The production function was estimated using data for 1967/70. It was hence inappropriate to use the derived function to estimate benefits for the earlier years.

Scheme averaged \$12,000. Hence, while net social benefits were negative, the average participant in the Group and Official Schemes gained private surpluses of some \$64 and \$24 per year respectively.

Table 3 also shows the estimated net social benefits for the Group Scheme using the production function model. The procedure involved use of the coefficients on the herd-recording variables in Table 2 to estimate the contribution this practice made to on-farm milk production. These increments were summed over all Group recorded cows in all regions to estimate the fraction K for use in equation (9).¹¹ The value of λ , the long-run elasticity of supply of dairy products, was calculated from the

¹¹ In the last eleven years the calculation indicates that Group herd-recording in N.S.W. has increased total milk production in Australia by approximately 0.21 per cent (i.e. an average K value of 0.0021), or by some 14.8 Ml., annually.

work of Mules [8] at $+0.875$.¹²

The average annual net social benefit of the Group Scheme since 1960-61, using the production function model, was \$175,000. This is well in excess of the annual loss of \$67,000 estimated from the input demand model. The discrepancy may be partly explained by the likelihood that the \$175,000 includes a return to the better managerial expertise of the herd-recording farmers. The extent of this bias is unknown however. The input demand estimates are hence preferred because they do not have such biases.

The Richmond-Tweed-Clarence region apparently gained the largest increment in milk yield per cow from Group herd-recording, followed by the Murrumbidgee-Murray, Hastings-Hunter and the South Coast. Herd-recording appears not to have increased milk yield in the Sydney-Illawarra region. The increments in milk yield due to herd-recording in Appendix Table 1 vary inversely with the yield per non-recorded cow from the B.A.E.'s survey (see Appendix Table 2). This supports the hypothesis of many dairy extension officers that farmers with low initial milk yields have most to gain from herd-recording. However, the reason also could be that they have latent managerial ability. The Group herd-recording fee charged per cow ranged from \$1.09 to \$2.21 from 1961 to 1971. Subtracting these and the cost of lodging for the recorder from the value of milk increments shown in Appendix Table 1 indicates a net profit per cow per year of \$18 for the Richmond-Tweed-Clarence, \$5 for the Murrumbidgee-Murray and Hastings-Hunter, -\$1 for the South Coast and -\$4 for the Sydney-Illawarra, when milk is valued at the equalized manufacturing price, including the bounty and skim milk component.

The average annual net farm income of those farms that herd-recorded over the three years 1967-68 to 1969-70 was \$7,154, compared with \$6,042 for those that did not. These means were significantly different at the 10 per cent level ($t = 1.82$). The total cost of Group herd-recording in 1970-71 was \$5.31 per cow, 66 per cent of which was subsidized by the state and federal governments. The herd-recording farmers in the B.A.E. survey had an average of 71 cows. Hence they received an annual subsidy of about \$205 when their incomes were already higher than non-participants. If the fee were increased to cover the full cost, the input demand models indicate that demand for Group herd-recording might fall by some 75 per cent. Appendix Table 1 suggests the bulk of those remaining in the scheme would come from the Richmond-Tweed-Clarence region, and to a lesser extent from the Murrumbidgee-Murray and Hastings-Hunter regions.

Estimated Value of Artificial Breeding

The value of the practice of artificial breeding on dairy farms was calculated by using the coefficients on the B variables for each region (Table 2) in equation (8). The base yields (Q_1^*) for each region were calculated in this instance from data averages from the B.A.E. survey. These are shown in row (1) of Table 4.

Again, with the qualification that the artificial breeding variable may

¹² The slope estimates of Mules' linear supply equations were used to derive supply elasticities at the mean levels of his data, which were kindly supplied to the author by Dr Mules.

have an inherent management bias, it appears that this practice has improved milk yields per cow in the Richmond-Tweed-Clarence and Hastings-Hunter regions of the state. Lesser effects are recorded in the Sydney-Illawarra and Murrumbidgee-Murray regions. A nil impact is indicated for the South Coast. The current charges for artificial insemination are \$5.50 to \$6.50 for semen from proven bulls. With milk valued at the historical equalized manufacturing price plus bounty of \$0.0484 per litre, these figures indicate farmer annual net profits of \$18 and \$5 per cow for the Richmond-Tweed-Clarence and Hastings-Hunter regions, respectively. Negative net returns are indicated for the other regions.

When the production function was run with artificial breeding included as a continuous (\$'s) variable for each region, the resulting *t*-values on the artificial breeding and herd-recording coefficients were generally lower than the fitted model in Table 2. The MVP of artificial breeding at the geometric mean data levels amounted to \$177 for the Richmond-Tweed-Clarence, \$38 for the Hastings-Hunter, \$8 for the Sydney-Illawarra, zero for the South Coast and \$55 for the Murrumbidgee-Murray region.

TABLE 4

Estimated Effects of Artificial Breeding (B) on Milk Production and its Interaction with Herd-Recording (H)^a
(Litres per cow)

	Richmond- Tweed- Clarence Region	Hastings- Hunter Region	Sydney- Illawarra Region	South Coast Region	Murrum- bidgee- Murray Region
(1) Yield without B or H (Q:*)	1,664	2,478	3,082	2,391	2,514
(2) Increase in Yield with B only	520	252	105	nil ^d	119
(3) Increase in Yield with H only	484	154	nil ^d	70	183
(4) Increase in Yield ^b with B and H	1,004	406	546	680	648
(5) Increase in Yield due to B over and above H ^c	682	268	546	628	499

^a Base yields from which the increments due to B and H were calculated using the coefficients of the production function were derived from B.A.E. Dairy Industry Survey data from 1967-68 to 1969-70.

^b This consists of the sum of rows (2) and (3) plus the effect of the interaction term (Region x H x B) in the production function. The hypothesis that the coefficient on (Region x H x B) was zero against the alternative that it was positive was not rejected for the RTC and HH Regions. Hence no complementarity was indicated between H and B in these Regions.

^c The base yield from which the B increment was calculated was the sum of rows (1) and (3).

^d The hypothesis of a zero coefficient on this variable in this Region, against the positive alternative, was not rejected. Hence the nil effect postulated here.

APPENDIX—TABLE 1
Estimated Effects of Group Herd-Recording (H) on N.S.W. Milk Production by Regions

Year	Richmond-Tweed- Clarence Region		Hastings-Hunter Region		Sydney-Illawarra Region		South Coast Region		Murrumbidgee- Murray Region	
	Yield per Cow Recorded	Portion of Yield due to H	Yield per Cow Recorded	Portion of Yield due to H	Yield per Cow Recorded	Portion of Yield due to H	Yield per Cow Recorded	Portion of Yield due to H	Yield per Cow Recorded	Portion of Yield due to H
60-61	1,664	1/cow 375	2,216	1/cow 128	2,877	1/cow nil	2,335	1/cow 66	2,331	1/cow 156
61-62	1,878	422	2,376	137	2,942	"	2,303	65	2,447	163
62-63	1,728	388	2,273	130	2,933	"	2,147	61	2,462	164
63-64	1,813	406	2,363	135	2,922	"	2,170	61	2,446	162
64-65	1,687	378	2,240	128	2,786	"	2,018	57	2,508	166
65-66	1,746	390	2,410	137	2,785	"	1,914	54	2,470	163
66-67	1,961	438	2,667	152	2,998	"	2,244	63	2,608	171
67-68	1,979	441	2,663	151	2,951	"	2,062	58	2,290	150
68-69	1,819	404	2,730	154	3,049	"	1,827	52	2,634	172
69-70	2,203	488	3,056	173	3,388	"	2,422	68	2,946	192
70-71	2,044	452	3,014	170	3,439	"	2,533	72	3,011	197
71-72	2,191	485	3,250	184	3,670	"	2,388	68	2,977	194

^a From herd-recorded cows in the region.

A strong complementary relationship between herd-recording and artificial breeding is indicated for all regions, particularly the Richmond-Tweed-Clarence, South Coast and Murrumbidgee-Murray, as shown in row (4) of Table 4. Ignoring any management biases, annual net returns per cow in excess of \$33 from the conduct of both practices are indicated for the former region and in excess of \$28 for the other two. In the Hastings-Hunter and Sydney-Illawarra regions, annual net returns above \$8 per cow are suggested by the analysis. Row (5) of Table 4 further illustrates the complementarity between herd-recording and artificial breeding. Artificial breeding introduced onto a farm which already uses herd-recording results in much larger milk yield increases than when it is introduced on a farm which does not herd-record.

The evidence cited here of the complementarity between herd-recording and artificial breeding endorses the recently announced policy of the N.S.W. Department of Agriculture [9]. The new programme closely integrates herd-recording and artificial breeding in N.S.W. into a herd-improvement programme. The aim is to obtain optimal genetic improvement in dairy cattle by urging farmers to engage in both practices [5]. The previous analysis certainly suggests that herd-recording on its own has doubtful economic value.

Conclusions

It appears that the overall social net benefits from the Group and Official Herd-recording Schemes in New South Wales may have been less than their social costs. However, except for those in the Sydney-Illawarra region, dairy farmers who have participated in Group herd-recording earned positive net private returns.

APPENDIX—TABLE 2

Average Yield per Cow from Farms in the B.A.E. Dairy Industry Survey in N.S.W.^a
(Litres per cow)

	Richmond- Tweed- Clarence Region	Hastings- Hunter Region	Sydney- Illawarra Region	South Coast Region	Murrum- bidgee- Murray Region
Farms with neither H nor B ^b	1,664 (103)	2,478 (55)	3,082 (31)	2,391 (93)	2,514 (54)
Farms with B only	2,146 (22)	2,741 (32)	3,150 (71)	2,300 (9)	2,746 (15)
Farms with H only	2,205 (41)	2,587 (30)	2,764 (14)	2,414 (11)	2,809 (62)
Farms with both H and B	2,473 (19)	2,882 (20)	3,191 (37)	2,314 (10)	3,223 (13)

^a These are the raw statistics from the B.A.E. Survey. Figures in brackets refer to the number of farm-year observations in each category.

^b H refers to herd-recording and B to artificial breeding.

Artificial breeding was shown to have increased milk yields in all regions except the South Coast but private net returns were positive only in the Hastings-Hunter and Sydney-Illawarra regions. No evaluation of the net social benefits of artificial breeding was undertaken in this study.

It is only by an integration of herd-recording and artificial breeding into a herd improvement programme that increased social benefits can be expected. The historical rate of genetic gain in New South Wales dairy herds has apparently been only 0.1 per cent per annum. If the newly integrated programme can increase this to the apparent potential of one per cent or more, then the future social gains could be much greater than the disappointing figures obtained in the past.¹³

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¹³ The 0.1 per cent figure has been estimated by K. Hammond of the N.S.W. Department of Agriculture (private communication 1973). The one per cent is close to the estimated annual rate of genetic gain in milk yield in Scandinavian countries as collated by J. Rendel of F.A.O. (private communication 1973), but somewhat above the figure of 0.5-0.6 used by Hinks [7].