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AGRICULTURAL DEVELOPMENT SYSTEMS EGYPT PROJECT

UNIVERSITY OF CALIFORNIA, DAVIS

THE OPPORTUNITY COST OF ANIMAL LABOR
IN EGYPTIAN AGRICULTURE

by

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Agricultural Development Systems:
Egypt Project
University of California
Davis, Ca 95616

Introduction

For nearly twenty years, the focus of investments in Egyptian agriculture has been on reclaiming land under the so-called New Lands program. Unfortunately, for reasons ranging from poor soils to unresolved management and administration problems, the results of these efforts have not lived up to initial expectations and in many areas, New Lands projects have yet to make a positive contribution to the Egyptian economy. With the recent influx of development-oriented foreign aid, both aid donors and Egyptian policy makers have begun to reconsider their priorities and to examine the possibilities of additional investments in the Old Lands as a means of reducing the country's growing dependence on food imports.

One of the most frequently suggested means of increasing the productivity of the Old Lands has been increased mechanization. Egypt is somewhat of an anomaly in that its agricultural sector is characterized by high yields and high cropping intensities, but low levels of power inputs. As a consequence, it has been argued that even though current productivity is relatively high by developing country standards, the climate and soils are such that these could be increased still further by the introduction of certain types of improved mechanical technology. In particular, it is argued that the continued use of milk animals as a major source of power constitutes not only a constraint on the timeliness of various types of agricultural operations, but that the continued reliance on animals has a very high opportunity cost in terms of the country's limited land and water resources.

The following paper seeks to contribute to the resolution of this

argument by developing an estimate of the opportunity cost of animal labor that can be compared with the advantages of mechanization in a standard cost-benefit analysis. As a point of departure, the first section of the paper discusses estimates of the value of animal labor made by various consulting groups that have required such estimates as the basis for project evaluation in the fields of tractor mechanization and the mechanization of low lift irrigation. The estimates are complicated by the fact that most animal labor is provided by milk animals and hence, the estimates are shown to vary widely and to be based, in several cases, on either implausible assumptions or questionable empirical evidence. Subsequently, an alternative set of estimates is developed with the aid of econometric techniques. The paper concludes with comments on the implications of the various estimates for project analysis.

A Review of Estimates for Animal Labor Cost

The simplest approach to the calculation of animal labor costs is that taken in what will be called Estimate I of the FAO/World Bank feasibility study of mechanization in Sohag and Menufiya governorates. It simply attributes the entire feeding cost on working days to the cost of animal labor. In so doing, the estimate is, of course, not the marginal cost of animal labor from foregone production, but the average cost. Maintenance feed requirements, which are a fixed cost, have not been separated out in this approach. (For future reference, the cost of animal labor using this method is 9.8 piastres per animal hour.)

A more sophisticated approach is followed in the second calculation by the FAO/World Bank study (Estimate II). The marginal cost of animal

labor is assumed to be the meat and milk production that is foregone due to the animal's labor, keeping the level of feed constant. From assumptions about milk yield, calving rate, body weight and calf mortality, the total loss in production is valued at 16.9 piastres per animal-hour. Meat loss accounts for 10.9 piastres per hour, while milk loss is put at 6.0 piastres.

The same method of estimating losses in meat and milk production is also used in the study done by ERA 2000, but with different results. Losses are calculated for both cows and buffalo. Based on the consultants' assumptions, the cost of cow labor totals 6.6 piastres per hour due to a 4.7 piastre milk loss and a 1.9 piastre meat loss. Buffalo labor costs 6.8 piastres per hour, composed of a 6.3 piastre milk loss and a 0.5 piastre meat loss. Not only are these estimates of 6.6 and 6.8 piastre total loss significantly lower than the FAO/World Bank's estimate of 16.9 piastres, the difference is even greater when comparing meat loss alone, 1.9 and 0.5 piastres versus 10.9 piastres for the FAO/World Bank study. (See Table 1 below for a comparison of the estimates.)

The feasibility study by Louis Berger International does nothing to resolve the inconsistencies in the estimates of foregone meat and milk production. Their estimate of the milk loss alone due to an animal-hour of labor is 11.3 piastres, nearly double the two previous figures for milk loss. In addition to 3.8 piastres for meat loss, 9.4 piastres is computed as the cost of additional feed consumed by the livestock on working days. Consequently, their estimate of the marginal cost of animal labor is the highest yet, 24.5 piastres per hour.

El Tambadawy's master's thesis, based on a farm survey, also

TABLE 1

Loss in Meat and Milk Production due to Animal Labor

Source	Milk Loss (piastres/hr.)	Meat Loss (piastres/hr.)	Total Loss (piastres/hr.)
FAO/World Bank	6.0	10.9	16.9
ERA 2000			
-Cattle	4.7	1.9	6.6
-Buffalo	6.3	0.5	6.8
Berger International	11.3	3.8	24.5*
El Tambadawy's farm survey			
-Work less than 4 hr./day	0.0	NA	0.0
-Work more than 4 hr./day	3.6	NA	3.6

*The total loss includes 9.4 piastres per hour for extra feed due to working.

includes an estimate of the loss in milk production incurred when animals are used for both milk and draught power. Farmers generally report that there is no loss in milk yield if the animal is worked less that 4 hours per day. However, if the animal is worked more, the evening milking is less productive and generates a cost of 3.6 piastres per animal-hour. This is the smallest reported estimate of production foregone and could be due to the fact that the farmer only notices the sharp drop in a single milking and neglects slight losses over the next few days. Also, if the animal is worked regularly, the losses could be reflected over the whole milking season and the farmer would be unaware of the true long-term milk losses.

The rental market in working animals is still another alternative source of estimates on the opportunity cost of animal work, which should be reflected in the market price. The first column in Table 2 compares the observations on market price of animal work with the previous estimates of meat and milk loss.

TABLE 2

Estimates of the Opportunity Cost of Animal Labor

Source	Total Cost (piastres/hr.)	Hours per year to irrigate feddan
FAO/World Bank - Estimate I		
-Average feed cost	9.8	143
FAO/World Bank - Estimate II		
-Meat/Milk loss	16.9	143
ERA 2000		
-Cattle meat/milk loss	6.6	198
-Buffalo meat/milk loss	6.8	198
Berger International		
-Meat/Milk loss plus extra feed	24.5	176
El Tambadawy		
-Work less than 4 hr./day	0.0	78
-Work more than 4 hr./day	3.6	78
ERA 2000		
-Market price for rental	19.0	198
Farmer Survey - 1979		
-Market price for rental	33.0	87

ERA 2000 utililzed a farm survey to find the rental market price in its feasibility study. The average price was 19 piastres per hour, but farmers' responses ranged from 10 piastres to 30 piastres. In the author's own survey of farmers, rental prices ranged from zero to 50 piastres per hour, even excluding the ones that borrowed from relatives without charge. The non-relatives reporting no rental charge were all in the same village and custom apparently dictates that the renter feeds the animal and pays nothing. The variance in the answers was quite large and although the mean response was 33 piastres per hour, the median was 50 piastres per hour!

The rental market price of animal labor is compared with the other

estimates of the opportunity cost of animal labor in Table 2, summarizing three disturbing patterns in the estimates. First, the various estimates provided by consultants vary widely, both in the absolute total loss and in the proportion of the loss being due to foregone milk production (Table 1). Second, a high variation was found in the reported rental prices. And third, the average rental prices for animal labor were higher than all but one of the foregone production estimates, indicating that most consultants are underestimating the cost of animal labor, if animal rental markets are operating properly to reflect the true costs.

Livestock Data

The unavoidable conclusion from this background research is that more effort appears necessary to uncover a reliable estimate of the marginal cost for animal labor. Luckily, some data is available for this investigation. El Tambadawy has carefullly surveyed 120 farmers from Sharkia governorate on livestock production in 1977/78. Information on milk yields, feed utilization and animal labor has been gathered for the farmers' 100 buffalo and 62 cattle that were producing milk. This detailed information permits the fitting of milk production functions that include hours of farm work as an independent variable and hence, yields quantitative estimates of the loss in milk yield due to farm work.

Before detailing the production function estimation, some of the livestock of the dairy animals' characteristics are outlined in Table 3. The most obvious pattern is the dichotomy between summer and winter seasons. Feed utilization, measured in total digestible nutrients (TDN)

is concentrated in the winter, being more than double the summer level. The relative difference between summer and winter is even greater in digestible protein (DP) utilization because the winter feed consists almost entirely of the protein-rich berseem crop. The sources of TDN and DP are detailed in Tables 4 and 5, which are derived from feed values given in Morrison. The obvious seasonal pattern is consistent with figures reported by El Tobgy that show 3.83 million tons of TDN available nationally in the winter and only 1.70 million tons for the summer.

TABLE 3

El Tambadawy's Livestock Survey
Sample Means for 62 Cattle and 100 Buffalo

	Cattle		Buffalo	
	Winter	Summer	Winter	Summer
Daily Milk Yield (kg.)	4.61	2.19	6.98	4.40
Lactation Period (days)	146	91	160	112
Milk Production (kg.)	750	158	1201	401
Milk Price (piastres/kg.)	11.7	12.1	12.9	13.1
Total Digestible Nutrients (kg.)	794	383	1017	502
Digestible Protein (kg.)	126	28	163	37
Hours Worked	37.1	88.2	40.7	85.4
Percentage of work in irrigation	96	93	98	95
Age of Animal	7.3		7.8	
Value of Animal (Egyptian pounds)	194		265	

The utilization of animal labor also involves a seasonal pattern. However, the concentration is the opposite of the seasonal feeding because the hours of animal labor required in summer are more than double those needed during the winter months. (The reason for the heavy work load during the summer is the heavy demand for irrigation services at that time.) Therefore, the livestock must provide the majority of

TABLE 4

Feed Values

Source of Nutrients	Units for Conversion	Percent TDN	Percent DP
Berseem	1 feddan = 6 ton/cut	11.8	1.9
Rice Plants	kilogram	20.8	0.3
Wheat Straw	kilogram	40.6	0.3
Fool (bean)	kilogram	73.4	22.1
Mixed feed	kilogram	71.6	12.0
Maize leaves and tassles	1 feddan = 1.3 tons	10.4	1.2
Miscellaneous Feeds - Bulk	approx. by value	9.7	1.0
Misc. Feeds - Concentrates	approx. by value	71.6	12.0

their labor during the period of feed shortage.

Specification of a Milk Production Function

The disaggregtion of the data collected by El Tambadawy into winter and summer seasons allows the estimation of separate seasonal production functions. The feed situation differs drastically in the two seasons, so that two production functions are a necessity. The dependent variable is average daily milk yield in grams during seasonal lactation.

TABLE 5

Feed Utilization

Total Digestible Nutrients

	Cattle		Buffalo	
	TDN in kg.	% of total	TDN in kg.	% of total
WINTER				
Berseem	785	66.7	1011	66.6
Rice Plants	10	0.8	6	0.4
SUMMER				
Wheat Straw	249	21.2	317	20.9
Fool (Broadbean)	46	3.9	54	3.6
Mixed Feed	18	1.5	20	1.3
Maize Leaves/Tops	31	2.6	44	2.9
Miscellaneous	39	3.3	67	4.4
Total	1177	100.0	1519	100.0

Digestible Protein

	Cattle		Buffalo	
	DP in kg.	% of total	DP in kg.	% of total
WINTER				
Berseem	126.4	82.1	162.7	81.4
Rice Plants	0.1	0.1	0.1	0.1
SUMMER				
Wheat Straw	1.8	1.2	2.3	1.2
Fool (Broadbean)	14.0	9.1	16.3	8.2
Mixed Feed	3.0	1.9	3.3	1.7
Maize Leaves/Tops	3.6	2.3	5.1	2.6
Miscellaneous	5.1	3.3	10.2	5.1
Total	154.0	100.0	200.0	100.0

TABLE 6

Animal Labor

Working Hours per Season

	Cattle		Buffalo	
	Winter	Summer	Winter	Summer
Irrigation	35.5	82.0	40.0	81.4
Planking/Puddling	0.6	2.3	0.5	1.0
Plowing	0.3	0.1	0.2	0.4
Furrowing	0.8	3.8	0.0	2.6
Total	37.1	88.2	40.7	85.4

Number of Animal Working Each Operation
(Total Animals: 62 Cows, 100 Buffalo)

	Cattle		Buffalo	
	Winter	Summer	Winter	Summer
Irrigation	61	61	98	98
Planking/Puddling	13	41	19	41
Plowing	5	1	3	3
Furrowing	7	48	0	59

The variables used in the equations are given below:

Y = Average daily milk yield (grams)

A = Age of animal (years)

N = Total digestible nutrients (kg. per season)

P = Digestible protein (kg. per season)

W = Animal work (hours per season)

L = Lactating days (days from calving)

The independent variables with the exception of age are seasonal variables. Feed utilization and working hours are measured on a seasonal basis and interest centers on the effect of working an animal one more hour in a particular season. The dependent variable, however, is <u>daily</u> milk yield. Seasonal milk production was not used because of the confounding effect of the lactation period. Therefore, average daily milk yield is the more appealing variable and must be multiplied

by the average seasonal lactation period (from Table 3) to measure seasonal milk production.

The following production relationships need to be estimated:

(1) $Y_{ij} = f(A_i, N_{ij}, P_{ij}, W_{ij}, S_{ij})$

i = (cattle,buffalo)

j = (winter,summer)

There are a total of four separate equations, two seasonal production relationships for cattle and two for buffalo.

The production function is not the simple input-output type with all independent varibles representing variable inputs. Age and days lactating are quality variables, effectively equivalent to fixed inputs. Animal work is by no means an input, instead it represents a joint product. The coefficient of animal work measures the product-product relationship between milk and work. Finally, TDN and DP utilization are the classical variable inputs and would adhere to traditional factor-product relationships.

Thus, the relationships between independent variables and dependent variables are of three types - variable factor-product, fixed factor-product and product-product. With this heterogeneous mixture of theoretical relationships, the selection of a functional form for the production function becomes difficult. The habitual Cobb-Douglas function has appeal for describing variable input-output relationships but may fail to capture the other relationships. Consequently, alternative functional forms were estimated and compared.

The most critical functional relationship to be captured is the product-product interaction between animal work and milk yield which measures the loss in milk production due to animal labor. Two separate

functional relationships between the products are proposed, linear and logarithmic. The two functional types below will be called linear and logarithmic because of the product-product functional form, despite the presence of quadratic terms. Dropping the subscripts in equation (1), the two forms are:

$$(2)\ Y = K + \beta_1 A + \beta_2 A^2 + \beta_3 N + \beta_4 N^2 + \beta_5 W + \beta_6 S$$

$$(3)\ \ln Y = \ln K + \beta_1 \ln A + \beta_2 (\ln A)^2 + \beta_3 \ln N + \beta_4 \ln W + \beta_5 \ln S$$

Where K is the constant term and each equation would be estimated four times, two seasonal functions for each type of animal.

Age has been entered in a quadratic form in both linear and log functions because a simple linear or log function would allow only monotonically increasing or decreasing relationships which would be incapable of capturing the interaction. TDN utilization is also used in the quadratic form in the linear production function to permit decreasing marginal returns to TDN. Finally, DP utilization has been dropped in this exercise because of its high degree of correlation with TDN.

The suitability of the functional form can be tested using covariance analysis. Specifically, the regression coefficient for the work variable when work is at low levels is compared to the coefficient for high levels of work by introducing two dummy varibles that allow an intercept and slope change for high levels of work. Equation (4) shows how the two dummy variables, D_1 and D_2, are introduced into the linear equation.

$$(4)\ Y = \beta_0 D_1 + K + \beta_1 A + \beta_2 A^2 + \beta_3 N + \beta_4 N^2 + \beta_5 W + \beta_6 S + \beta_7 (D_2 W)$$

The residual sum of squares from the original equation and from the equation with dummy variables are compared to test if the new variables

account for a significant portion of the variation in Y. If this is significant, the work-milk yield relationship is different for low levels and high levels of work and the functional form should be rejected. The results of the F-test in Table 7 are not entirely conclusive. The table shows that none of the linear functional forms can be rejected but the log function for cattle during the summer can be rejected at the .01 significance level.

The log-log relationship between work and milk yield is theoretically unappealing because it assumes a constant elasticity. This means that an increase in working hours from 10 to 20 would result in the same percentage loss in milk production as increasing working hours from 100 to 200. This implies a sharply diminishing absolute loss in production as working hours increase. The survey by El Tambadawy suggests just the opposite because, according to farmers, less than 4 hours of work per day results in no milk loss. However, increasing daily hours of work caused a loss in milk, implying an increasing absolute loss as work hours increase.

The evidence presented shows that the linear function best satisfies the relationship between work and milk yield. Furthermore, the strength of the Cobb-Douglas function, which is a decreasing marginal value product for variable inputs, has been preserved in the linear equation by introducing TDN and DP in a quadratic form.

Estimation of Milk Production Functions

The results from the regressions for cattle are presented in Table 8. Equation A is the estimation of equation (2) above. The second estimation for summer, equation B, includes two additional variables so

TABLE 7

F-Test for Uniform Animal Labor Coefficient and Intercept at Low and High Levels of Animal Labor

	Linear Equations				Log Equations			
	Cattle		Buffalo		Cattle		Buffalo	
	Winter	Summer	Winter	Summer	Winter	Summer	Winter	Summer
Regression Coefficients for Animal Labor:								
(1) Low levels animal labor	-50.57	-20.27	-11.83	-10.24	-.0498	-.0085	-.0333	-.0148
(2) High levels animal labor	-9.23	-4.30	-10.35	-3.23	-.1265	-.3762	-.1133	-.0449
F-Statistic	.87	.80	.11	1.31	.26	5.73**	.38	.06
Degrees of Freedom	2,53	2,53	2,91	2,91	2,54	2,54	2,92	2,92

** Significant at .01 level

F-statistic measures difference in residual sum of squares between the two equations. Equation (1) is standard estimated equation and equation (2) allows the slope and intercept to change when animal labor is at above average levels.

that DP utilization enters in a quadratic form. Because berseem is virtually the only winter fodder, winter DP utilization is almost perfectly correlated with winter TDN and consequently could be dropped from the equation. The TDN coefficient represents both the return to TDN and DP that is in the fixed ration of berseem.

Table 9 presents the results from the regressions for buffalo. The equations were estimated twice, first with all observed buffalo and then without the buffalo having unusual lactation periods. The lactation period for buffalo is longer than that of cattle and it appears that the variable for days lactating does not capture fully the milk production effects of abnormal lactation periods. Most buffalo lactate for two to four months in the summer and five to six months in the winter. However, a few animals were recorded as lactating for the full six months in the summer and only two or three months in the winter. The second set of regression equations shown in Table 9 were estimated without these outlying observations. The assumption that the excluded animals would have different regression coefficients and not the simple intercept change assumed with the days lactating variable necessitated the exclusion of these unusual lactations.

The estimated equations have low coefficients of multiple correlation, R^2, that range from 0.09 to 0.36. These low R^2 are partly due to the missing variables of genetic endowment and animal weight that would ordinarily be expected to have a significant impact on milk yields. (The implications of these missing variables is discussed in Appendix A.)

From the results in Tables 8 and 9, the most consistent relationship appears to be between the two age variables and output. The milk yield

TABLE 8

Cattle Milk Production Function

Independent Variable	Unit	Symbol	Winter Eqn. A	Summer Eqn. A	Summer Eqn. B
Age	yr.	A	-719*	-736**	-737**
			(281)	(262)	(263)
Age squared	yr.	A^2	36.8*	39.8**	39.7**
			(16.0)	(14.8)	(14.8)
TDN	kg.	N	3.76	32.3**	27.1*
			(6.21)	(9.4)	(12.9)
TDN squared	kg.	N^2	-0.0026	-0.0331*	-0.0279+
			(0.0038)	(0.0107)	(0.0162)
DP	kg.	P			54.8
					(47.8)
DP squared	kg.	P^2			-0.620
					(0.780)
Animal labor	hours	W	-10.0+	-7.89*	-7.64
			(6.0)	(2.99)	(3.10)
Days lactating	days	L	-28.1**	3.01	4.50
			(9.7)	(5.96)	(6.03)
Regression Statistics					
Constant		K	8,759	-1,950	-1,991
Coefficient of Multiple Correlation		R^2	.28	.33	.36
Number of Observations			62	62	62

Standard errors in parentheses
Dependent Variable: Average daily milk yield in grams
+ .10 level of significance
* .05 level of significance
** .01 level of significance

TABLE 9

Buffalo Milk Production Functions

			Winter		Summer			
			All Obs.	Same Lactation	All Observations		Same Lactation	
Ind. Variable	Unit	Symbol	Eqn. A	Eqn. B	Eqn. A	Eqn. B	Eqn. A	Eqn. B
Age	yr.	A	-505*	-486+	-522*	-534*	-767**	-632*
			(234)	(253)	(234)	(239)	(249)	(247)
Age squared	yr.	A^2	26.6*	25.7+	26.1*	26.5*	38.3**	32.0*
			(12.6)	(13.6)	(12.6)	(12.8)	(13.4)	(13.2)
TDN	kg.	N	-5.06	3.54	3.33	3.43	12.6	13.9
			(3.50)	(4.21)	(7.24)	(7.39)	(10.8)	(10.7)
TDN squared	kg.	N^2	0.0031+	-0.0018	-0.0024	-0.0024	-0.0108	-0.0130
			(0.0016)	(0.0021)	(0.0071)	(0.0072)	(0.0101)	(0.0099)
DP	kg.	P				10.1		-71.6
						(41.5)		(49.4)
DP squared	kg.	P^2				-0.167		1.15
						(0.494)		(0.62)
Animal labor	hours	W	-13.7*	-18.9**	-0.28	-0.25	0.60	1.89
			(5.9)	(6.6)	(3.21)	(3.30)	(3.87)	(3.95)
Days lactating	days	L	-19.9*	-29.1	-6.81	-7.29	-19.8*	-17.2+
			(9.3)	(22.9)	(5.13)	(5.28)	(9.7)	(9.7)
Regression Statistics								
Constant		K	12,928	10,221	7,079	7,071	8,271	7,755
Coefficient of Multiple Correlation		R^2	.21	.28	.09	.09	.23	.31
No. of Observations			100	58	100	100	58	58

Standard errors in parentheses
Dependent Variable: Average daily milk yield in grams
+ .10 level of significance
* .05 level of significance
** .01 level of significance

decreases through the first years of milk production and then reaches a minimum and begins to increase again. (The age of minimum milk production is given in Table 10.) Lest this should appear to be counter-intuitive, these results point to a systematic culling of animals and the elimination of the marginal producers in their later years. For example, Figure 1 shows the age distribution of the sample and indicates that animal numbers, and thus, culling begins after age 8. The number of cattle or buffalo in the 9 to 10 year age group is one half the number in the seven to eight year age group. Therefore, the relationship between age and milk production is capturing the selection process going on within the herd and not the behavior of an individual animal as it ages.

TABLE 10

Age and Daily Milk Yield

	Cattle		Buffalo	
	Winter	Summer	Winter	Summer
Minimum milk yield at age:	9.8	9.3	9.5	9.9
Average age	7.3		7.8	
Range of ages	3-15		3-16	

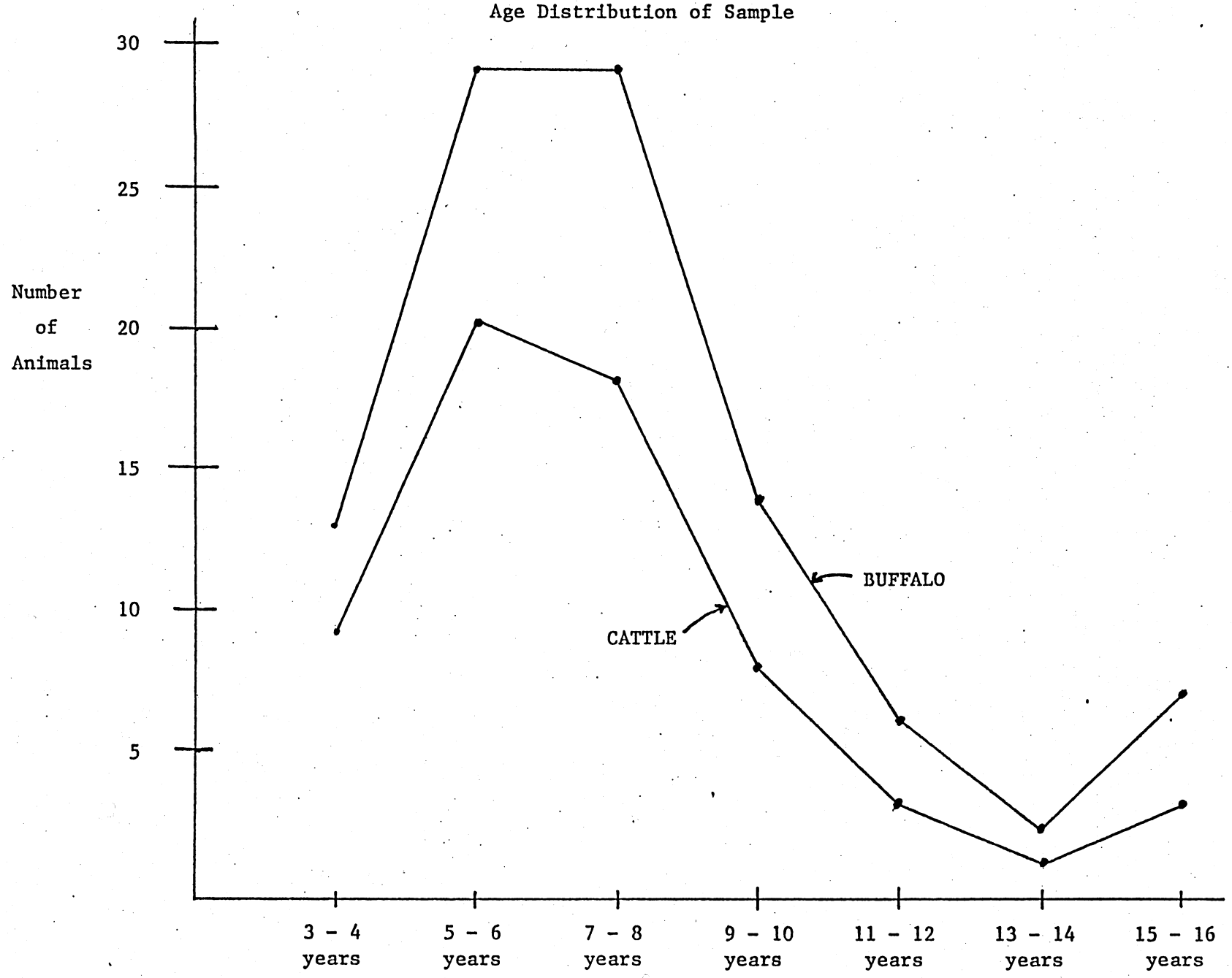
The variable for days lactating has, in general, a negative effect on milk yield. Barret and Larkin note this characteristic in dairy animals and attribute this fall in milk yield to the increasing fetal demand of the again-pregnant cow. The regressions seem to reflect accurately the expected relationship.

Marginal Value Products

The marginal value products of TDN, DP and animal work have been

FIGURE 1

Age Distribution of Sample



calculated in Table 11. The marginal value products for winter TDN are -0.6 piastres per kilogram for cattle and -0.2 piastres per kilogram for buffalo. Both are essentially zero because feed is simply no constraint to winter milk production. The animal is being fed to gain weight during the winter in order to survive the near-starvation levels of feed during the summer. Feed levels are not set at the level simply to maximize profits for winter milk production, but also to store energy for the summer period.

TABLE 11

Marginal Value Products and Costs

	Units	Cattle Winter	Cattle Summer	Buffalo Winter	Buffalo Summer
TDN MVP	piastres/kg.	-0.6	6.3	-0.2	1.2
TDN cost	piastres/kg.	6.9	7.4	6.9	7.4
DP MVP	piastres/kg.		22.1		19.8
DP cost	piastres/kg.		20.9		20.9
Work MVP	piastres/hr.	-17.1	-8.4	-38.9	2.8

MVP calculated by multiplying marginal product of daily milk yield by average days lactating to get seasonal impact in grams, and then multiplying by the price of milk per gram.

Equation A used for winter estimates and equation B (with DP) for summer estimates. Buffalo estimates are for same lactation period only.

The marginal value products for summer TDN are more indicative of profit maximizing behavior. The cost of TDN is 7.4 piastres per kilogram, compared to its marginal value product for cattle of 6.3 piastres per kilogram. This suggests some overfeeding but farmers are obviously near the point of marginal returns equaling cost.

For buffalo the marginal value product of summer TDN is 1.2 piastres per kilogram, quite low compared to the cost of 7.4 piastres. The

summer buffalo production function estimates are therefore unsatisfactory. In particular, the fact that the marginal value product is only slightly positive and the feed response surface is quite flat raises serious doubts about these estimates. (The estimate of the marginal value product of DP for summer buffalo is therefore also suspect despite its agreement with the input cost.)

The summer cattle's marginal value product of DP, 19.8 piastres per kilogram, is quite close to the input cost of 20.9 piastres. The response surface reflected in the quadratic form of DP is very curved, despite the coefficient estimates being, in general, not significantly different from zero.

The marginal value product, or imputed cost, of animal labor is given in the last row of Table 11. The estimates are surprisingly high when compared to the other estimates that were reviewed in Table 1. The estimates are consistent in that the greatest loss for both buffalo and cattle is during the winter season when milk yields are the highest. Again, the summer buffalo estimate is unsatisfactory, and given the consistency of the other three equations, clearly wrong.

Because of the need for a consistent estimate of the cost of summer buffalo's labor for calculating the benefits of mechanization, the estimate was taken from earlier equations in Table 7 where separate regression coefficients were estimated for high and low levels of animal labor. The coefficients from the linear equation for summer buffalo in Table 7 are -10.24 and -3.23, which correspond to marginal value products of -15.0 and -4.8 piastres per hour for low levels and high levels of work, respectively. Thus, 15.0 piastres per buffalo-hour as the marginal cost of animal labor was used as the summer buffalo

estimate because of the need for consistent estimates.

In order to accurately reflect the total on-farm opportunity costs of animal labor the regression estimates must be adjusted for (1) the extra feed farmers provide animals during working days, (2) the percentage of milk animals not producing milk and not incurring foregone production and (3) the meat loss associated with animal labor.

During work periods, farmers supplement the animal's feed, resulting in a partly compensating effect on milk production due to the feed response and an extra loss in the form of higher feed costs. The extra feed on summer working days, as reported by twenty farmers in Sharkia governorate, amounts to 16% more straw and 82% more fool (broadbean) than on non-working days. Thus, the additional increase in feed is largely concerned with providing additional protein to the animal.

This reported feed supplement for work totals to 0.62 kilograms TDN and 0.11 kilogram DP per hour of work for cattle compared to 0.82 kilogram TDN and 0.15 kilogram DP for buffalo. The milk production increase due to this feed has been calculated and the total cost of work is allocated to decreased milk production and increased feed costs in Table 12. The feed response function for cattle was used for both cattle and buffalo because of the difficulty in estimating the summer buffalo feed response. No extra feed was assumed for the winter because of the already high levels of nutrition at that time of year.

The estimates in Table 12 have also been adjusted to incorporate those animals not in milk. The sample for the regression estimates included only those cows that produced milk in the last year. Therefore, the equations' estimates of milk loss must be weighted by the percentage of animals in milk during the year, under the assumption that

TABLE 12

Opportunity Cost of Animal Labor
(piastres per hour)

	Cattle		Buffalo	
	Winter	Summer	Winter	Summer
Milk loss - feed constant	-12.8	-6.3	-29.2	-11.3
Milk gain from extra feed		1.2		2.1
Cost of extra feed		-1.5		-2.0
Meat loss - assumed	-4.2	-4.2	-3.6	-3.6
Opportunity Cost	-17.0	-10.8	-32.8	-14.8

milk and non-milk animals are worked similarly. Winrock International reports calving rates in Upper Egypt ranging from 40% to 80%, indicating a wide variation in the number of non-milk cows. El Tambadawy's survey reports higher yields than those in Upper Egypt; hence, the assumption will be that the calving rate is also high in the Delta and that approximately 75% of cows are in milk at some time during the year.

Table 12 also includes a measure of the meat loss due to working. Following the assumption of high calving rates, further improvements in meat production from decreasing animal labor will be assumed limited by already high calving rates. Nevertheless, calf mortality could decrease dramatically due to release from animal work. Therefore, a 20% drop in meat production has been assumed for an animal working 200 hours per year. Consistent with the milk production losses, this estimate should set the uppper bound for possible meat loss. It totals to a 4.2 piastre meat loss per hour of cattle labor and a 3.6 piastre loss for buffalo. These estimates are arbitrary and should be improved by deriving them in a similar manner to the econometric estimates of milk loss in this paper. Yet, because the meat loss is a small portion of the total opportunity cost of animal labor, making errors in these estimates is less important than the errors in estimating foregone milk production.

Conclusions

A comparison between the final calculations in Table 12 and the previously reviewed estimates in Table 2 shows that the econometric estimates are at the high end of the scale. Therefore, with the exception of Berger International's calculations, consultants appear to be underestimating the cost of animal labor in Egyptian agriculture. However, according to my survey, the consultants overestimate the annual animal labor requirements for irrigation of a feddan (Table 2) so the combined effect on their mechanization recommendations is uncertain.

Appendix A suggests that the omitted variables could have biased these results and that consequently the opportunity cost of animal labor may be overestimated. The evidence presented in Appendix A indicates, however, that the effect is likely to be minimal. Furthermore, the econometric results correspond most closely with the prices in the rental market for working animals which should be accurately reflecting the opportunity cost of animal labor. All in all, these estimates seem reliable and are an attempt at quantitatively deriving the potential benefits of mechanization.

Appendix A

The problem with the regression estimates in Tables 8 and 9 are that they suffer from the classical problem of specification bias; genetic endowment and animal weight are omitted variables because no data are available on them. Hence, it is useful to sketch the implications of this bias in the classical manner outlined by Griliches.

Assume the true equation for the real world is:

$$(1)\ Y = a_1x_1 + a_2x_2 + \ldots + a_kx_k + u$$

where y is the dependent variable, a_i the regression coefficient, x_i the independent variable and u is the error term.

If x_k was unobservable or for any reason omitted from the equation, the expected value of the estimated coefficient for any x_i will be biased. The expected value of the biased coefficient, a_i, is equal to:

$$(2)\ E(a_i) = a_i + pa_{ij}a_j$$

where p_{ij} comes from the regression of the excluded variable on all included variables, as below.

$$(3)\ x_k = p_{1k}x_1 + \ldots + p_{k-1,k}x_k + v$$

Therefore, the bias in the estimate of a_i, namely a_i, depends on both the coefficient for the excluded variable and the relationship between the excluded variable and x , allowing for the relationship with other included variables as in equation (2).

Hence, omitted variables are no problem if their coefficient in the true, full equation is zero or if the partial correlation between the excluded variable and the variable of concern is zero. The concern with the milk production functions is that high-producing dairy animals would work less because they face the greatest possible loss in production. Thus, this plausible inverse relationship between animal labor and

labor was with days lactating in the winter buffalo function and the summer cattle function. However, one relationship was positive and the other negative and the effected bias in both equations was quite small, offering no evidence of the expected relationship.

The relationship between animal labor and age portrayed in Table A is a complicated one because age enters in a quadratic form. However, if age were a variable affecting hours of animal labor because of the consistent relationship between age and milk yield, animal labor should be positively correlated with the linear age variable and negatively correlated with the squared age variable. In fact, the correlations are always of the same sign for both the linear and squared term, indicating that animal labor does not have the same relationship with age as it does with milk yield. It appears that neither of the quality variables measured have a close association with animal labor. If this lack of association between animal labor and quality variables, as measured by equation (3), extends to the unmeasured variables of genetic endowment and animal weight, then the problem of omitted variables' bias on the work coefficient can be ignored.

After more thought, the independence of animal labor from quality variables is quite rational because of the absence of markets to distribute the labor load between animals. Instead, the typical farmer owns one or two dairy animal and works them fairly evenly on irrigation days so neither gets strained and so the work gets done in the minimal time. The small ownership patterns prevents the type of specialization implied by concentrating animal labor on the unproductive animals. There is further evidence of this from El Tambadawy's finding that there is no difference between the hours of labor for buffalo and for cattle.

genetic endowment implies that p_{ij} from equation (2) would be negative. The regression coefficient for genetic endowment would certainly be positive making the bias in the estimated coefficient for work more negative than its true value. That is, part of the regression coefficient could be capturing the decision to work the better milk producers less.

The direction of the potential bias due to animal weight is unclear. Even though animal weight would have a large positive impact on milk yield the interaction between animal labor and animal weight is indefinite. It's plausible that heavier animals work more hours per season because they are more powerful, resulting in a less negative estimate of the cost of animal labor from the estimated equation. Whatever the case, it would probably have less of an impact because p , the coefficient for weight on animal labor, would likely be small.

This type of analysis is useful in determining that the omission of variables could cause an overestimate of the marginal cost of animal labor. Despite the importance of this, there are two pieces of evidence that suggest these calculations may not be overestimates, or if they are, only slightly biased from the true values.

First, some measure of the impact of genetic endowment or animal weight can be abstracted from the similar quality variables included in the estimated equations, namely animal age and days lactating. The assumption being that these included quality variables interact with the work variable in the same manner as the two omitted variables would. Regressions are run as in equation (3) to estimate the relationship between the included quality variables and work, giving an estimate of p_{ij}. Table 1 shows that the only significant relationship with animal

TABLE A

Estimation of Equation 2 Assuming
Dependent Variable as Missing Variable

Dependent Variable	Cattle Winter	Cattle Summer	Buffalo Winter	Buffalo Summer
Age	-0.0027	0.0087	-0.0078	-0.0031
	(0.0233)	(0.0077)	(0.0176)	(0.0110)
Age squared	-0.125	0.150	-0.221	-0.096
	(0.247)	(0.136)	(0.326)	(0.204)
Days lactating	-0.089	-0.154*	0.078*	0.072
	(0.082)	(0.064)	(0.038)	(0.054)

Standard errors in parentheses
* .05 level of significance

Buffalo, despite being superior milk producers, averaged 125.3 hours of labor per year, compared to cattle's 125.1 hours.

In summary, the problem with the omitted variables of genetic endowment and animal weight could bias the regression estimates to overestimate the marginal cost of animal labor. However, this is dependent upon an inverse relationship between the missing quality variables and hours of animal labor and this is not supported by the available measured quality variables including the type of animal -- buffalo versus cattle. Therefore, the problem with overestimation may either not exist at all, or at least be minimized.

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