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MECHANIZATION DECISIONS IN EGYPTIAN AGRICULTURE

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Introduction

The dominant constraint of Egyptian agriculture has been its limited land base. With the completion of the Aswan Dam in 1963, adequate year-round water supplies became available for Egyptian farms and, except for site-specific instances, removed water as a constraint to agriculture. Under these circumstances, it is easy to see why major efforts have been underway for over a decade to reclaim "New Lands". However, progress in creating economically profitable units has been painfully slow. As a consequence, much attention has been focused on "intensification", the full development of the potential of the "Old Lands".

A prime concern of intensification in Old Lands has been the mechanization of agricultural operations. The United States Agency for International Development (AID) has funded a $55 million mechanization project and the World Bank has implemented a $30 million development project planned for Sohag and Menufiya governorates, concentrating on mechanized inputs. Proponents of agricultural mechanization, as well as the project appraisal reports for the AID and World Bank projects, claim large social benefits from the further mechanization of Egyptian farms. These appraisal reports are forced to make sweeping assumptions on the benefits of mechanization because the empirical work estimating these benefits has not been done.

This report will attempt to estimate empirically the parameters associated with the benefits of mechanization.[1] In the second section, the claims in the AID and World Bank appraisal reports will be evaluated in order to outline specific empirical hypotheses. The third and fourth sections discuss the data used in the analysis and then proceed with the empirical estimation. The final section draws conclusions from these tests and relates the importance of these findings to Egyptian price policy.

The following analysis focuses on existing technological alternatives in Egyptian agriculture. Future mechanization plans, however, will clearly involve new machines and new operations to mechanize. For example, self-powered thresher/winnowers may replace the current tractor-powered drum threshers and the tractorization may be expanded to include planting and cultivating operations. (The tightest labor constraints are during wheat and cotton harvesting and farmers desire to cut labor use during these times.) It is appropriate, therefore, that the study of present technologies not only relates to current issues but also addresses concerns that are likely to surface again with these new technologies.

<u>Benefits of Mechanization</u>

Project appraisal reports [2] contain similar claims of the benefits from mechanization. With widespread concern for the effects of labor displacement, the stress is placed on benefits from increased agricultural production; the possible displacement of labor is downplayed. Much of the reports' discussion is devoted to the argument that labor saved through mechanization will be counterbalanced by increased labor demand from yield and cropping intensity improvements.

Because of the importance of the agricultural output effects of mechanization, this section will examine carefully the potential for yield increases and cropping pattern changes that might be undertaken given adequate mechanization. Following the look at the agricultural outputs, the input side will be examined through the cost savings in human labor and animal labor resulting from farm mechanization.

Yields

Yield increases for most crops are an important source of benefits for mechanization. Table 1 summarizes the assumption by various reports on the yield increases due to mechanization in Egyptian agriculture. These assumptions for tractorization are normally based on sketchy research station experiments that vary plowing techniques and planting dates. It is assumed that these results are transferrable to the farm, and yields are increased due to improved seedbed preparation and due to timely planting allowed through mechanization.

Table 1

Assumed Yield Increases from Mechanization Package

Study	Cotton	Maize	Wheat
ERA 2000-tractor	9%	9%	9%
ERA 2000-tractor/harrow	31%	32%	24%
World Bank-package	10%	15%	10%
AID-package	10%	10%	10%

The key question is the extent to which agricultural research results on mechanization are comparable to actual farmers' results. This issue is important because it would indicate those farm conditions which negate the research station results. For example, the availability of a tractor does not insure proper seedbed preparation. In earlier farm surveys, farmers indicated that tractors plow at a shallower depth than animals. This suggests that the extra power of tractors is not being used for improved seedbed preparation. Also, farmers' planting dates are a complex decision involving a number of factors, not solely the availability of primary tillage. In the case of cotton, planting is often delayed to allow extra cuttings of the profitable berseem crop. It is therefore questionable that farmers would plant earlier with improved tractor services.

The argument for yield increases are similar for all types of mechanization. It asserts that the improved technology performs a superior job that increases yields and does the job more quickly, allowing more timely completion of the operation. For example, mechanized irrigation does a more timely and thorough job of watering. Wheat threshing can result in sharply reduced grain loss and shortening the threshing period further reduces losses. Unfortunately, the extent to which positive effects actually occur usually depends on a wide variety of farm interactions and hence the contributions of mechanization are inevitably confounded with other variables.

Cropping Pattern Changes

Proponents of mechanization argue that the timeliness of operations provided by new technologies not only increases yields, but also affects the cropping pattern. The most beneficial change would be double cropping on farms that were previously only growing one crop annually. Therefore, the whole farm may double its cropping intensity. More likely, the cropping intensity will increase but not to the extent of a doubling the intensity. AID [1979] assumes, for example, that an eight feddan cotton farm will increase its cropping intensity from 180 to 200 percent and that rice farms will increase from 170 to 200 percent. Dramatic production increases result from these assumptions and, if true, are often sufficient to produce significant economic rates of return to mechanization projects.

Mechanization may also change the cropping pattern to more profitable crops, either combined with an increase in cropping intensity or while maintaining the same cropping intensity. The value of production would increase because mechanization allows more flexibility in the crops grown, and a more profitable cropping pattern. The more profitable cropping pattern may, of course, only be financially more profitable. Greater income is returned to the farmer, but not to society. The serious price distortions in output prices known to exist in the Egyptian agricultural sector make this possible and suggest the careful use of social cost-benefit analysis in the study of mechanization.

Labor Savings

Mechanization normally reduces the labor requirement by performing tasks more rapidly. The extent of this reduction is a critical factor in appraisal reports. Whereas these savings could be the most signigicant benefit in mechanization, the possible social cost of labor displacement in "labor surplus" countries undermines this claim in appraisal reports. Nevertheless, AID [1979] projected a 42 percent drop in labor utilization on the typical eight feddan rice farm, a savings of 138 Egyptian pounds (L.E.). Without this savings the net benefits of mechanization would drop 24 percent.

Livestock Displacement

Most forms of mechanization under consideration in this paper replace animal power with mechanical power. The savings from the animal pwer is an important benefit from mechanization in the mechanization appraisal reports. For example, AID [1979] expects a L.E. 351 increase in meat and milk production through reductions in animal labor. If livestock production does not increase, the net benefits would fall by 62 percent to L.E. 133. Again, this assumption is critical to the social profitability of mechanization.

The social benefits from animal labor saving is dependent on how they are realized. As Cuddihy [1978] reports, the domestic markets in meat are heavily protected through import restrictions, whereas the major field crops (excluding fodder) are taxed. If the reduction in animal labor requirements results in reducing the number of farm animals, forage crops can be replaced with field crops having a high economic price. But if animals are kept for milk and meat production after being released from farm work, the net social benefits could be substantially different.

Farm Management Survey Data

The empirical estimation of the benfits from mechanization presented below utilizes a portion of the data collected in the MOA Farm Management Survey of 1977. Two samples were selected from the entire data set, one for Lower Egypt and one for Upper Egypt. The data for Lower Egypt focused on the region of Sharkia Governorate, comprising 11 villages from the governorate and nearby regions. The Upper Egypt sample includes 10 villages from both Upper and Middle Egypt.

Empirical Estimation of Mechanization Benefits

The actual estimation of mechanization benefits is not an easy task. At first thought, it would seem to be a simple matter of comparing mechanized to non-mechanized farms and to invoke the "with" and "without" methodology of benefit-cost analysis. However, as Binswanger [1978] has noted, a whole series of potential confounding factors enter into any direct comparison between mechanized and non-mechanized farms. For example, the mechanized farms may have had more access to credit to buy fertilizer than non-mechanized farms. In this case, the estimation must allow for the contribution of fertilizer input to yields and must not attribute that part of the yield difference to mechanization.

Fertilizer's effect on yields is only an example. There are a whole range of possible confounding factors, biasing benefits in favor of either mechanized or non-mechanized farms. Binswanger carefully reviews South Asian empirical work that considered the effect of some of these factors, including farm size, irrigation, fertilizer, labor and the use of high-yielding varieties. The importance of these factors in Egyptian agriculture will be evaluated in a future paper, comparing the use of these factors by size of farm and level of mechanization.

Yields

The estimation of yield benefits requires the use of covariance analysis, which for yields is the equivalent of estimating a production function with dummy variables for each type of mechanization. The benefits from mechanization can then be interpreted as the coefficient of the dummy variable, using a t-test to evaluate the coefficient's statistical signifigance.

The Cobb-Douglas production function estimated for each crop was of the general form:

$$Y = a + bP + cI + dN + eM + fH + gF + hS$$

where all variables in logs except dummy variables:

Y = yield in ardebs per feddans
P = dummy variables for type of plowing
I = dummy variables for type of irrigation
N = inorganic nitrogen fertilizer
M = organic fertilizer
H = hired labor in days
F = family labor in days
S = size of field in feddans

Tables 2 and 3 present the results of the covariance analysis. The fit of the equations is not very good, with R squared being quite low. The important input factors do not have consistently significant coefficients and, at times, have the wrong sign. However, when input factors have the wrong sign they are never statistically significant and there are consistencies across equations that make discussion of the results worthwhile.

The effect of field size on yields differs significantly between the two regions. In Lower Egypt the coefficient for

TABLE 2

COVARIANCE ANALYSIS ON YIELDS
LOWER EGYPT

	Intercept	Plowing Technology: Animal	Plowing Technology: Mech.	Plowing Technology: None	Irrigation Technology: Animal	Irrigation Technology: Mech.	Irrigation Technology: Gravity	Nitrogen Fertilizer	Manure	Hired Labor	Family Labor	Field Size	No. of Obs	R^2
Wheat	5.80*	0.09	0	0	-0.01	0	–	0.20*		-0.03	0.15*	0.01	111	0.20
	(11.32)	(0.19)	(0.02)		(0.15)			(2.43)		(0.71)	(3.19)	(0.20)		
	8.70*	0.25	0	–	0.17	0	–	-0.02	-0.38*	-0.11	0.20	-0.15	34	0.45
	(7.24)	(1.30)			(1.07)			(0.13)	(2.24)	(1.09)	(1.94)	(1.06)		
Maize	7.72*	-0.03	0	–	-0.04	0	–	-0.11		-0.01	0.02	-0.28*	92	0.21
	(12.43)	(0.34)			(0.40)			(1.08)		(0.31)	(0.44)	(3.80)		
	6.54*	0.08	0	–	-0.12	0	–	-0.06	0.17	0	0.03	-0.17*	71	0.31
	(9.04)	(0.99)			(1.34)			(0.57)	(1.79)	(0.12)	(0.57)	(2.59)		
Rice	6.53*	0.63*	0.63*	0	0.07	0	0.20	0.19*		-0.06	-0.08	-0.26*	101	0.33
	(13.10)	(2.00)	(2.15)		(0.97)		(0.77)	(2.10)		(1.53)	(1.63)	(4.16)		
	7.21*	0.09	0	–	-0.01	0	-0.35	0.25*	-0.12	0	-0.06	-0.31*	76	0.42
	(15.72)	(0.90)			(0.12)		(1.04)	(2.30)	(1.42)	(0.05)	(1.19)	(4.78)		
Perm. Berseem	4.13*	-0.12	0.14	0	0.16	0	1.55*	0		0.04	0.07	-0.07	50	0.15
	(5.39)	(0.43)	(0.73)		(0.84)		(2.27)	(0.02)		(0.54)	(0.94)	(0.57)		
Short Berseem	2.86*	0.11	-0.10	0	0.02	0	–	0.11		0	0.18*	-0.19	32	0.35
	(3.23)	(0.42)	(0.68)		(0.15)			(0.60)		(0.13)	(2.18)	(1.69)		
Cotton	6.28*	-0.32	-0.11	0	0.04	0	–	-0.01		0.12*	0	-0.13*	85	0.22
	(12.07)	(1.25)	(0.47)		(0.54)			(0.16)		(2.96)	(0.12)	(2.39)		
	5.35*	-0.21	0	–	0.04	0	–	-0.04	0.22	0.09	-0.02	-0.10	63	0.22
	(6.74)	(1.88)			(0.34)			(0.34)	(1.81)	(1.64)	(0.45)	(1.34)		

* - significant at 5% level

Note - number in parentheses is T-statistic

TABLE 3
COVARIANCE ANALYSIS ON YIELD
UPPER EGYPT

	Intercept	Plowing Technology: Animal	Plowing Technology: Mech.	Plowing Technology: None	Irrigation Technology: Animal	Irrigation Technology: Mech.	Irrigation Technology: Gravity	Nitrogen Fertilizer	Manure	Hired Labor	Family Labor	Field Size	No. Obs.	R^2
Wheat	6.34*	-0.01	-0.20	0	0.34*	0	-	0.09		0.0	-0.01	0.08	72	0.24
	(13.34)	(0.14)	(1.39)		(4.00)		-	(0.99)		(0.17)	(0.16)	(1.48)		
	6.15*	0.42	0.47	0	-0.38	0	-	0.10	-0.09	-0.13	0.38*	0.12	18	0.75
	(6.92)	(1.60)	(1.55)		(1.23)		-	(0.70)	(0.73)	(1.06)	(3.67)	(1.05)		
Maize	3.71	0.03	1.05	0	0.32	0	-	0.40		0.19	-0.02	0.20	35	0.50
	(1.93)	(0.09)	(2.00)		(1.56)		-	(1.39)		(1.09)	(0.19)	(1.88)		
	4.68*	-1.01*		0	1.04*	0	-	0.01	0.15	0.15	0.32*	0.43*	10	0.97
	(2.92)	(2.74)			(3.91)		-	(0.04)	(1.12)	(0.51)	(3.42)	(4.43)		
Sorghum	6.37*	0	-0.15	0	-0.03	0	0.06	0.16		-0.12	-0.04	-0.08	46	0.05
	(5.69)	(0.01)	(0.28)		(0.15)		(0.14)	(0.90)		(0.98)	(0.37)	(0.40)		
	11.46	-0.51	-2.20	0	-0.02	0	0.58	-0.15	0.04	-0.72	-0.65	0.47	13	0.31
	(1.12)	(0.27)	(0.36)		(0.01)		(0.21)	(0.13)	(0.01)	(0.44)	(0.48)	(0.29)		
Sugar-cane	2.23*	0		0	0.07	0	0.19*	0.09		0.13*	0.08*	-0.02	38	0.59
	(6.04)	(0.03)			(0.38)		(2.46)	(1.51)		(2.98)	(2.32)	(0.52)		
Cotton	3.70*	0.07	0.50*	0	0.58*	0	0.15	0.42*		-0.08	0.08	0.13	21	0.87
	(5.11)	(0.59)	(2.42)		(3.29)		(0.58)	(3.71)		(1.37)	(1.43)	(1.66)		

* - significant at 5% level

Note - number in parentheses is T-statistic field size is negative in nine of the ten equations and statistically significant in five of the estimations. Hence, there appears to be higher yields on the small farms, a characteristic attributed to the higher input levels that small farmers frequently use. In contrast, Upper Egypt's equations have positive coefficients in six of the eight estimations but are signigicant in only one case. The higher yields on large farms could be due to Upper Egypt's slower pace of development -- enabling only large farmers to utilize the best techniques.

The major issue of the covariance analysis on yields is mechanization's effect on yields. For Lower Egypt, animal plowing has superior yields over tractor plowing in five out of ten cases. However, the significant differences are for tractor plowing's increase in yields for cotton and the superiority of both animal and tractor plowing over no tillage in the rice crop. In Upper Egypt, the significant differences are between tractor plowing and both animal plowing and no tillage for maize and cotton -- with tractor yields being superior. All other effects were insignificant.

The fact that the better yields for mechanized tillage appears in maize (for Upper Egypt) and cotton (for both regions) is interesting in light of informal field interviews. Farmers inidicate that they typically use more plowings for these two crops than for wheat, sorghum, rice or berseem. Therefore, if seedbed preparation was to be signigicantly better with tractors, the cotton and maize crops would be the expected recipients of the additional attention. The wheat crop, for example, usually receives only a single tractor plowing -- hardly adequate to improve yields through improved seedbed conditions.

Even though maize and cotton are probably the crops most sensitive to timely planting, this is not the reason for the improved yields as there was no difference between tractor and non-tractor farms in planting dates. This result is expected given the method of tractor use in Egypt. Tractors are not utiliized solely on the owners' farms, but also provide hired services that give access to mechanical inputs to all farmers in the village. Therefore, a single tractor is likely to be kept busy through the entire planting season until all fields had been planted. As a result, when planting dates for tractor and non-tractor farms were compared, there was no difference due to both technologies being used over the entire planting season.

Farms utilizing animal plowing could even show more timely planting because the large supply of animal power allows some concentration of work in the critical planting period whereas the tractor is fully utilized until all plowing is finished. In this case, animal plowing would have an earlier average planting date than the tractor. Nevertheless, the tractor could improve planting dates by adding to the plowing capacity of the village. The effects would appear, however, at the village level in a before and after tractor comparison and not through a cross sectional farm survey.

There are general indications to support the claim that the introduction of tractors reduces the period of operations at the village level, even though our cross sectional data provided no evidence. During informal field work in 1979, certain villages in Upper Egypt with very few tractors utilized a combination of tractor-powered threshers and animal-powered norags to accomplish the wheat threshing. Because of the constraint on power during this season, the wheat threshing for the village took 45 days to complete. In contrast, villages visited in Sharkia governorate had more tractors available and no longer required the norag to complete the threshing. In these villages the wheat threshing season varied from 15 to 30 days, depending on the number of tractors. Further work could estimate the exact relationship between tractor capacity and the wheat threshing period, but this general evidence supports the concept of village-level effects on timely operations that can not be uncovered with normal farm surveys.

The effect of irrigation technology on yields is also presented in Tables 2 and 3, but the results seem unclear. In Upper Egypt, animal water lifting had signigicantly better yields than mechanized pumping in three cases and gravity flow had one case of better yields than mechanized pumping. These results could be due to the quality of the land reflected in the irrigation technology or to the farmer's dependence on others for timely irrigation in the case of mechanized pumping. In Upper Egypt, some large stationary pumps are owned by individual farmers who sell the water to surrounding farmers. The dependence on this pump owner for water delivery may make timely irrigation more difficult than gravity flow and animal irrigation, where the farmer has more control over the irrigation operation.

Cropping Pattern Changes

One common argument for increasing the mechanization on farms is that it allows for changes in cropping patterns, either increasing the cropping intensity or switching to higher value crops. The greater benefits would come from increasing cropping intensity. A regression was done to test the effect of mechanization on cropping intensity, again controlling for confounding factors. The independent variables were the confounding farm characteristics that might influence cropping intensity plus an index for mechanization, varying from zero to one, that represented the percentage of tilled land that was tractor plowed. The results from the regressions are reported in Table 4, with no significant effect from mechanization.

Table 4
Regression on Cropping Intensity

	Lower Egypt		Upper Egypt	
	Coefficient	T-stat.	Coefficient	T-stat.
Intercept	187.96	30.87	197.67	29.76
Farm size	-0.44	1.66	-1.25	2.65
Percent land owned	-2.58	0.48	-3.77	0.47
Education	-0.93	1.37	0.02	0.03
Mechanization index	0.63	0.08	-8.41	0.92

The effect of mechanization on the cropping pattern is more complex than the effect on cropping intensity. Not only do farm variables correlated with mechanization influence cropping patterns, but the calculated mechanization index is dependent on the cropping pattern because certain crops are more likely to not be tilled. Hence, for the regression analysis, the mechanization variable is derived partly from the cropping pattern itself. As a result, the mechanization index cannot be used as an independent variable in any regression on cropping pattern.

Because of being unable to analyze differences in cropping patterns in the same manner as yield and cropping intensity differences, Table 5 presents the percentage of farm land in certain crops by level of mechanization. The table is interesting but no causality can be inferred because the comparison has not controlled for the confounding factors. However, the government enforced cropping patterns allow little flexibility in changing crops and the pervasive double cropping would permit higher cropping intensities only through vegetable crops. Thus, the effects of mechanization on cropping pattern changes could be expected to be minimal in Egyptian agriculture.

Table 5
Cropping Pattern by Level of Mechanization

	Lower Egypt		Upper Egypt	
	Low Mech.	High Mech.	Low Mech.	High Mech.
Wheat	20.4%	29.7%	24.6%	29.3%
Berseem	66.8	41.0	27.5	37.7
Rice	35.1	20.8	-	-
Maize	21.2	20.9	12.9	19.1
Sorghum	-	-	28.4	40.2
Cotton	31.4	21.8	11.7	27.0
Other	9.5	36.3	35.7	29.0
Sugarcane	-	-	23.8	1.0
Dairy animals (per feddan)	0.81	1.13	0.45	0.43

Labor Savings

Agricultural machines are able to perform operations more rapidly than the traditional agricultural implements. The technical superiority in these machines is a simple measurement and the resulting labor savings from various machines is listed in Table 6. These will vary somewhat due to different farm conditions (soil condition, lift of water, yield) and to the number of laborers working with the machine. With labor still relatively cheap, most operators have many laborers working with the machine to keep the machine operating at full capacity.

Table 6
Labor Use by Type of Technology

	Man-Days (per feddan)	Child-Days (per feddan)
SEEDBED PREPARATION - COTTON		
Tillage - animal	4.0	-
Tillage - tractor	0.5	-
Harrowing - animal	0.5	0.5
Harrowing - tractor	0.125	-
Ridging - animal	0.75	-
Ridging - tractor	0.25	-
IRRIGATION - MAIZE		
Saquia	0.49	0.49
Pump - 5 h.p. diesel	0.41	-
Pump - 16 h.p. diesel	0.15	-
THRESHING/WINNOWING - WHEAT		
Norag/hand winnow	12.0	
Drum thresh/machine winnow	4.8	

Table 7 presents the statistics fom the Farm Management Survey on labor use by crop by technology used for plowing. As noted above, many interactions are taking place besides the simple technical superiority of the tractor. The purpose of this table is to show that mechanization permits a whole series of on-farm processes to change, making it difficult to estimate actual labor displacement. Nevertheless, the estimates for the previous table are valid as a measure of cost savings from mechanization.

Table 7
Labor Use by Level of Mechanization
(in man-days)

	Lower Egypt		Upper Egypt	
	Low Mech.	High Mech.	Low Mech.	High Mech.
Wheat	27.7	24.3	30.0	27.5
Berseem, long	29.0	21.7	69.0	35.1
Berseem, short	6.0	12.5	76.1	45.4
Rice	58.7	54.6	-	-
Maize	38.9	43.0	44.3	54.6
Sorghum	-	-	42.6	46.2
Cotton	76.0	68.0	69.8	53.1

Note: Low mech. group includes no tillage

Livestock Displacement

Another cost reduction from mechanization is the elimination of animal labor. In most countries specialized work animals are displaced and it is relatively simple to calculate the cost of keeping animals. However, Egyptian animal labor is normally done by multi-purpose animals that also provide milk and meat to the farm. Therefore, the cost of replacing animal labor with machine power depends on the farmer's decision to keep the animal or release it after purchasing a machine. The first task is to determine if mechanization affects the number of dairy animals on the farm.

Regression analysis was used to explain the number of dairy animals with independent variables on farm size, land tenure, man labor availability, child/woman labor availability, education and indices for both tillage mechanization and irrigation mechanization. The results of the linear regression are reported in Table 8. The most important factors in determining the dairy herd are farm size and child/woman labor availability. Man labor availability has little effect because livestock tending is not considered a man's job.

The mechanization of tillage had an unsignificant negative coefficient in Lower Egypt and a nearly significant positive coefficient in Upper Egypt. The positive effect of mechanization on the number of dairy animals, along with much lower herd numbers (see Table 5), indicate that a capital constraint may be limiting animal numbers in Upper Egypt because mechanized farms are less likely to face capital constraints.

Table 8
Determinants of Dairy Animal Ownership

	Lower Egypt		Upper Egypt	
	Coeff.	T-stat.	Coeff.	T-stat.
Constant	0.144	0.27	-0.042	0.05
Farm size	0.216	10.49	0.063	1.20
Tenure - percent owned	0.620	1.65	0.875	1.02
Man labor available	-0.052	0.44	-0.300	1.02
Child/Woman labor available	0.214	2.88	0.172	2.25
Education	0.095	2.05	-0.123	1.29
Tillage mech. index	-0.492	0.87	1.841	1.95
Irrigation mech. index	-0.549	1.44	-0.015	0.02

The same type of analysis was also performed for the number of specialized work animals on the farm -- donkeys and camels. These regressions are summarized in Table 9. No effect of mechanization on animal numbers was found. Thus, the cost reductions in mechanization are not realized through the displacement of these animals.

Table 9
Determinants of Work Animal Ownership

	Lower Egypt Coeff.	Lower Egypt T-stat.	Upper Egypt Coeff.	Upper Egypt T-stat.
Constant	1.061	3.62	0.074	0.23
Farm size	0.073	7.16	0.086	4.37
Tenure - percent owned	0.094	0.47	0.249	0.78
Man labor available	0.058	0.92	0.388	3.56
Child/Woman labor available	0.009	0.30	0.015	0.52
Education	-0.061	2.49	0.001	0.02
Tillage mech. index	-0.418	1.36	0.233	0.67
Irrigation mech. index	-0.131	0.64	-0.024	0.09

The results on dairy animals agree with the findings reported in Dyer [1981]. Farmers in Sharkia governorate reported they would not reduce the number of dairy animals if they completely mechanized their farm. The opportunity cost of animal labor as meat and milk losses was estimated. The fact that animal labor is costed through milk and meat production is crucial because of government policy in the livestock sector. Import restrictions on meat and milk have kept domestic prices above the international prices, making meat and milk the only farm commodities that are protected and not taxed. Domestic prices therefore overstate the costs of animal labor (and benefits from mechanization) in social benefit-cost analysis. The involvement of government policy is critical in the calculation of benefits to mechanization and will be more generally studied below.

Summary of Mechanization Benefits

The estimates of the yield benefits from mechanization represent substantial gains in yields over non-mechanized farms. Table 10 converts the estimates from the covariance analysis in Tables 2 and 3 to percentage terms for those equations having statistically significant coefficients for mechanization variables. If these estimates are true, the benefits from mechanization would be extremely high.

Table 10
Yield Benefits from Mechanization

	Lower Egypt		Upper Egypt	
	Tractor vs. Animal	Tractor vs. None	Tractor vs. Animal	Tractor vs. None
Rice	0.0%	87.8%		
Cotton	23.3	NS	53.7%	64.9%
Maize			177.3	191.5

No significant changes in cropping intensity or cropping pattern could be detected with the data. However, cropping pattern changes could take place at the village level because the efficient hire services markets operate to add the tractor power to the total available power in the village. This spreads the tractor out and prevents some farms from having execess tractor capacity and having higher cropping intensities. If this is the case, our data would not capture these benefits.

The cost reductions from mechanization are from labor reduction and animal labor savings. The technical labor savings are presented but do not fully capture the labor utilization effects of mechanization on the farm. The reduction in animal labor use does not result in animal displacement, indicating the importance of shadow pricing meat and milk in the cost-benefit analysis.

Conclusions

The above empirical estimates must be viewed in connection with current agricultural price policy. If prices were set at proper shadow prices, there would be no reason for the intervention in farm mechanization. But with dramatic price distortions in the agricultural sector, care must be taken in examining the specific sources of benefits and costs. Thus, the analysis has tried to pinpoint these sources with great care so social benefit-cost analysis can be accurately compared with the farmer's financial return to mechanization.

Tractors

The measurement of yield benefits to tractorization for maize and cotton was the most notable finding in the empirical work because Binswanger's [1978] review of empirical estimations of mechanization benfits in Asia found consistent reports of no yield differences between tractor and non-tractor farms. Although our findings must be viewed as tenative, they underlie the importance of cotton prices to Egyptian farmers. Domestic farmgate cotton prices are currently less than half of their shadow prices. If cotton yields are senstive to tractor tillage, farmers may be using socially suboptimal amounts of tractor time for tillage because of the low output prices. Just as farmers move fertilizer allocated for cotton to more profitable crops, tractor inputs may be underutilized for the cotton crop. Therefore, price policy may be influencing the allocation of tractor time because of the unequal taxation of crops in Egypt.

The above argument does not justify any subsidization or government intervention for tractors because the implicit tax on tractor use through low cotton prices is more than offset by the protection on meat and milk markets and the input subsidy on diesel fuel. The financial return to the farmer would still be greater than the economic return measured by cost-benefit analysis.

The area where cost-benefit analyses fails in interpreting Egyptian tractorization is in understanding the importance of minimum tillage or no tillage alternatives. The complex farm system permits virtually any crop to be grown without tillage, depending on the preceding crop. Therefore, the without assumption in tractor cost-benefit analyses of animal plowing is not completely justified. The effects of no tillage on crops must be studied because the prevalance is quite widespread. Fitch [1981] reports 19.3 percent of maize in the Delta and 26.9 percent in Middle Egypt uses no tillage. Our 1981 survey of Middle Egypt found 45 percent of the maize farmers and 35 percent of the cotton farmers using no tillage. None of the farmers used animal plowing for these crops. No tillage must be viewed as the alternative to tractor plowing, but it is extremely difficult to estimate the yield losses from no tillage.

Pumps

The empirical estimations reveal no benefits from pumps through yield increases, but discussions with farmers indicate that limited areas where water delivery is uncertain or the water level is highly variable may benefit from pumps. With this exception, the benefits from mechanized water lifting are achieved through cost reductions, but these benefits are derived chiefly through meat and milk production. The protected markets for meat and milk, combined with subsidies for diesel fuel, result in the financial returns for pumps outrunning the social returns.

The divergence between private returns and social returns in Egyptian agriculture has been increasing over due to the increasing domestic prices for meat and milk and a constant nominal price for diesel fuel. Tables 11 and 12 calculate the financial and economic costs of water lifting for saquias and six horsepower diesel pumps in two years -- 1977 and 1981. The share of total costs devoted to fuel in the economic analysis is substantial while the fuel cost share in the finanicial analysis is negligible. Tables 11 and 12 reflect the price distortions indicated above and suggest the source of much of the impetus for the mechanization of Egyptian agriculture.

Table 11
Financial and Economic Costs of Saquias - 1977 and 1981
(L.E. per typical irrigation -- one feddan)

	Financial		Economic	
	1977	1981	1977	1981
Fixed Cost	0.29	0.44	0.29	0.44
Milk Loss	0.58	1.20	0.58	0.96
Meat Loss	0.16	0.39	0.16	0.29
Repair/Maint.	0.11	0.16	0.11	0.16
Total Cost	1.14	2.19	1.14	1.85

Table 12
Financial and Economic Costs of Pumps - 1977 and 1981
(L.E. per typical irrigation -- one feddan)

	Financial		Economic	
	1977	1981	1977	1981
Fixed Cost	0.62	0.81	0.62	0.81
Fuel Cost	0.13	0.16	0.36	1.13
Repair/Maint.	0.19	0.25	0.19	0.25
Total Cost	0.94	1.22	1.17	2.19

The total costs from the tables show that saquias are more expensive than pumps at financial prices but cheaper when the analysis is done at economic prices. Admittedly, some of the assumptions behind these tables are debatable and labor costs are not included in this comparison. From a policy perspective, however, the interesting result shown in Tables 11 and 12 relates to the change in costs over time. While there may be some question regarding the technical coefficients used, the prices on which the calculations are based are solidly grounded in recent empirical observations.

For the period 1977 to 1981, the financial cost of saquia irrigation increased 92 percent (from L.E. 1.14 to L.E. 2.19) while the economic cost increased only 62 percent (from L.E. 1.14 to L.E. 1.85). The difference in the rates of increase are the result of rising domestic meat and milk prices that have raised the value of financial meat and milk lost above it economic loss. For pumps, the financial cost has increased only 30 percent (from L.E. 0.94 to L.E. 1.22) over this time period, while the economic cost has risen 87 percent (from L.E. 1.17 to L.E. 2.19). The difference in the rates of increase for pumps is due entirely to the subsidy on diesel fuel. The economic price for diesel has increased dramatically since 1977 because of the Iranian crisis, but the financial price has been raised only negligibly.

The distortions in the economy have worsened considerably over the last four years and have resulted in a even greater subsidy to pumping in the agricultural sector. Hence, the social desirability of pumps is distinctly different from investments for tractors. Whereas tractors have measurable output effects, the rationale for pumps is cost s..vings and is entirely financial in nature.

FOOTNOTES

1. The methodology used in our analysis is an extension of the methodology used in Binswanger [1978].

2. For examples of Egyptian mechanization appraisal reports see ERA 2000 [1979], AID [1979] and World Bank [1977].

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