Measuring Technical Efficiency of Wheat Farmers in Egypt

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André Croppenstedt
Agricultural and Development
Economics Division
Economic and Social Department
Food and Agriculture Organization
Italy
e-mail: andré.croppenstedt@fao.org

Abstract

Liberalization of Egyptian agricultural policy and new wheat technology has led to significant increases in area allocated to wheat as well as wheat yields. The wheat self-sufficiency ratio increased from 21 percent in 1986 to about 59 percent over the 2001-03 period. However, the country still imports 4-5 million tonnes of wheat per year. This paper addresses the issue of what kind of output gains can be achieved from improving technical efficiency, i.e. how much more output can be produced with the given levels of inputs and current technology. On average wheat farmers are found to operate 20 percent below the potential output. Better information on irrigation management and two or more extension visits were found to raise output by 14 and 7 percent respectively. However, neither factor was found to affect technical efficiency. Technical efficiency was found not to vary with farm size.

Key Words: Egypt, Wheat, Technical Efficiency, Stochastic Production Frontier.

JEL: C21, O13, Q12.

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Introduction

Since 1986 the Egyptian agricultural sector has undergone significant change. Prior to this date agricultural policy, as indeed economic policy more generally, had been interventionist, leading to widespread distortions. The impact of the latter on agricultural performance has proven difficult to assess for Egypt. Bruton (1983) and Antle and Aitah (1986) found that the interventionist environment impinged negatively on agricultural productivity in the country. On the other hand Esfahani (1987) and Alderman and von Braun (1986) found that a lack of investment, not price policies, were to blame for the poor performance of the sector. However, there was more general evidence linking interventionist policies to poor agricultural performance in developing countries (see Krueger, Schiff and Valdés (1992)). Liberalization of the sector was therefore seen as an important first step in transforming the economy to a more market oriented one.

Removing distortions was expected to improve the efficiency of resource allocation by producers and hence aid agricultural and economic growth. The focus on agriculture was natural since it was perhaps the most distorted sector of the Egyptian economy as well as being a very important one, accounting for 35% of the labor force and producing about 17% of GDP and about 11% of exported goods. The process of agriculture sector reform began in 1986 and included removing area allocation (except for cotton and sugarcane) and compulsory delivery, price restrictions (except for cotton and sugarcane), subsidies on fertilizer and pesticides and marketing restrictions for most major crops. More generally the reforms included the liberalization of domestic prices, exchange rates and interest rates, and removal of export and import restrictions.

The liberalization of the agricultural sector did have a significant impact on production. Agricultural output growth increased from 1.9 percent in 1971-80 to 3.1 and 4.5 percent in the 1981-90 and 1991-2000 periods, respectively. Cereal output growth increased from 0.5 to 5.2 and 5 percent for the same time periods. Growth accelerated dramatically in the second half of the 1980s. On a per-capita basis cereal output growth jumped from -1.7 percent in the 1971-80 period to 2.7 and 3 percent in the 1981-90 and 1991-2000 periods. The assessment of the impact on the efficient allocation of resources is mixed. Shousha and Pautsch (1997) do not find strong evidence that cropping patterns changed in response to changes in gross margins during the reform period.[1] On the other hand Baffes and Gautam (1996) found that crop profitability responds strongly to input and output prices and that the reform program had a positive effect on producer welfare for some commodities.

Apart from allocative efficiency, overall economic efficiency is also driven by changes in technical efficiency. The presence of technical inefficiency indicates potential output gains without increasing input use. Empirical work on this topic appears to be limited. Aly and Hassan (1994), using time-series data for 1950-90, estimate overall technical efficiency at 46 percent due mostly to operating at a non-optimal scale and less so from a pure-waste of resources. In this paper the focus is on measuring the level of technical efficiency in Egyptian wheat farming using wheat producer survey data.

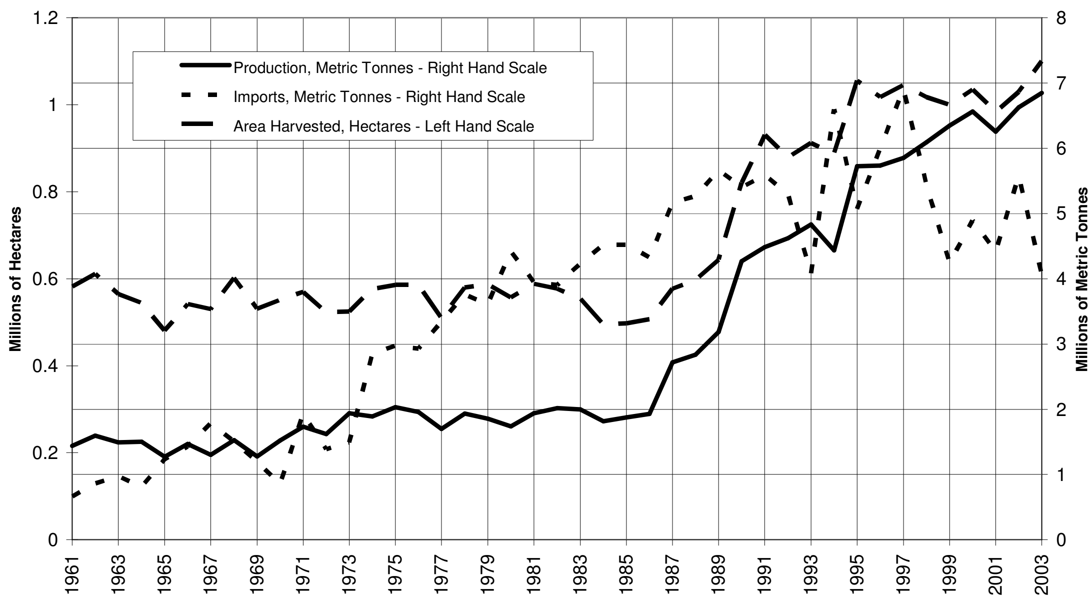
The Wheat Sector

Wheat occupies about 33% of the total winter crop area and is the major staple crop, consumed mainly as bread. More than one-third of the daily caloric intake of Egyptian consumers and 45% of their total daily protein consumption is derived from wheat. The

[1] They find that for 12 out of 16 crops there was no response.

reforms and the introduction of higher-yielding wheat varieties have led to increased wheat crop area, yields, and production. Wheat output growth jumped from 1.9 percent in 1971-80 to 10.3 and 4.8 percent in 1981-90 and 1991-2000, respectively. This has led to a rise in the self-sufficiency ratio from about 21% in 1986 to on average 59% over the 2001-2003 period. The government has been able to increase the quantity of domestic wheat it procured (for its subsidy program for *baladi* flour and bread) from less than 0.1 million metric tonnes in 1986 to 2 million metric tonnes in 2004. Nevertheless, while wheat self-sufficiency is often cited as a goal of Egyptian wheat policy, imports averaged about 4.7 million tonnes per year between 2001 and 2003.

Figure 1: Wheat Area, Production and Imports for 1961-2003



Source: FAOSTAT

Cultivated area for wheat started rising in the mid 1980s, at first only gradually but between 1989-91 quite rapidly in part due to land reclamation and development programs. After increasing in the 1980s indirect and direct subsidies for fertilizer, seed and fuel began to decrease in 1990 and were eliminated in 1993. Figure 1 and table 1 indicate significant increases in yield, area cultivated and production of wheat between 1985 and 1991, with production increases over the following decade being more modest.

Reforms have helped generate substantial increases in wheat output.[2] However a number of distortions remain and impinge on area and yield growth. In particular they include: 1) lack of small farmers access to improved varieties; 2) backward farm practices due partly to lack of agricultural extension, and; 3) limited access to farm inputs due in part to limited financial capacity particularly related to input markets.

[2] An in-depth analysis of the wheat sector and wheat policy reform can be found in Kherallah et al (2000).

Table 1: Levels and Growth Rates for Area, Yield, Production and Imports of Wheat for 1985-2002

Year	Area (Million Ha)	Yield (MT/Ha)	Production (Million MT)	Imports (Million MT)
1985	0.50	3.8	1.9	4.5
1991	0.93	4.8	4.5	5.6
2003	1.10	6.2	6.9	4.1
Years		**% average annual rate of change**		
1986-1991	11.3%	4.6	16.6%	3.9
1992-2002	1.6	2.3	3.9	0.4

Source: FAOSTAT

The Data

The 1998 Egypt Wheat Producers Survey (EWPS) was designed to be representative of farm households growing wheat in the 1997/98 season and covered 800 wheat farmers in 20 out of 26 governorates.[3] Some descriptive statistics of the sample are given in table 2.[4] Egyptian wheat farms are generally small and average land size is about 1.3 feddan (or 0.55 hectare). About 90% of land cultivated to wheat is owned by the farm household.

Irrigation is practically universal in Egyptian agriculture and this allows for the cultivation of summer and winter crops. Most irrigation is by pump from a canal, except in the Frontier region where irrigation comes from private and public wells. The most common winter-summer rotations are wheat-rice (20% of cultivated area), short-season berseem (clover)-cotton (12%), and wheat-maize (10%), and long-season berseem-maize (8%). Four-fifths of wheat farmers grow wheat every year.

Following liberalization of the wheat market and the introduction of modern wheat varieties most farmers use semi-dwarf varieties which are both higher yielding and more resistant to heat and pests. Fertilizer is no longer subsidized and by 1992 the fertilizer market's share of private traders was above 75%. On average sample farmers use 112 kilograms of fertilizer per feddan (N, P and K). The variable shows considerable variation with a range of 8 to 649 kg/feddan and 12 households report zero fertilizer use (including all 10 observations for Matruh governorate).

For the sample as a whole the proportion of labor being hired in is about 47 percent. Average family labor input is 18 man-days per feddan while it is 15.4 man-day per feddan for hired labor. Mechanical power is the combination of tractor power and water pumps (the definition used by Antle and Aitah (1986)). About 30 hours of machine time are used on a per feddan basis. Again there is a large degree of variation.

While 62 percent of household reported that better knowledge of plant disease and insects was the first and second most important type of information needed to improve yields, only 16 percent reported lack of irrigation knowledge was an important constraint. Only 34 percent of household heads claimed to be literate.

[3] The survey was undertaken by the International Food Policy Research Institute (IFPRI) in collaboration with the Ministries of Agriculture and Land Reclamation (MALR) and Trade and Supply of the Government of Egypt. The EWPS was funded under USAID Grant No. 263-G-00-96-000300. It is a four-stage stratified random sample that relied, in part, on lists of wheat farming households prepared by the (MALR). For details on the sampling design see IFPRI (1999).

[4] Unless otherwise indicated all descriptive statistics and regression results are obtained using sampling weights.

Table 2: Descriptive Statistics for Selected Variables

Variables	Variable Name	Mean	Standard Deviation	Range
Output/feddan in kilograms	--	2478	1167	563-12900
Land size in feddan	FEDDAN	1.3	1.8	0.08-15
Man-days of family labor	FAMLAB	12.4	11.1	0-223
Man-days of hired labor	HIRLAB	24.9	55.3	0-633
Man-days of total labor	TOTLAB	37.6	58.3	2.88-668
Man-days of family labor per feddan	--	18.1	15.8	0-90
Man-days of hired labor per feddan	--	15.4	15.2	0-124
Man-days of total labor per feddan	--	33.9	18.6	3.2-148
Family labor as a proportion of total labor	--	0.52	-	0-1
Hired labor as a proportion of total labor*	--	0.47	-	0-1
Fertilizer (N, P and K) kilogrammes	FERT	148.1	304.4	11.65-3204
Fertilizer (N, P and K) kilogrammes per feddan	--	112.1	72.6	8.1-649.2
Machine hours (tractors & water pumps)	MACHINE	34.6	58.0	0.3-640
Mule days	MULE	6.2	9.6	0-104
Machine hours (tractors & water pumps) per feddan	--	29.9	18.4	1.1-147.6
Mule days per feddan	--	8.7	16.8	0-173
Plant disease and insect knowledge is 1 if farmer considered that these were the 1st or 2nd most important types of information needed to improve wheat yields, 0 otherwise.	DISECTS	0.62	-	0-1
Irrigation management knowledge is 1 if farmer considered that this was the 1st or 2nd most important type of information needed to improve wheat yields, 0 otherwise	IRRIKNOW	0.16	-	0-1
Did an extension agent visit 2 or more times? yes/no	DUEXVIS	0.51	-	0-1
Age of the head of the household	--	50.8	13.4	18-95
Access to phone, yes/no	--	0.60	-	0-1
Proportion of household heads that can read & write, yes/no	--	0.34	-	0-1
Proportion of female headed household	--	0.11	-	0-1
Number of male adults	--	2.7	1.7	0-12
Number of female adults	--	2.4	1.5	0-14
Number of male children	--	1.1	1.3	0-8
Number of infants	--	1.0	1.2	0-9

*Remainder consists of exchange labor (added to hired labor in the regression).

Table 3 indicates that wheat yields did not vary statistically significantly by farm size.[5] With regard to input usage there are quite large differences in labor use, machine hours and mule days used per feddan. The substantially higher input use of family labor reflects the much higher ratio of household size to land holdings in the presence of what are probably limited off-farm opportunities. Access to credit is particularly low for the smallest farm size. Of concern is the fact that fertilizer on a per feddan basis is only 10 percent lower in the smallest farm size group as opposed to the largest farm size group (although this difference is not statistically significant), but higher than in the middle two categories. Very likely this is due to measurement error and I return to this issue in the results section.

[5] Farm size groups were chosen so as to produce four groups roughly equal in numbers.

Table 3: Descriptive Statistics for Key Variables by Land Size

	Farm Size in Feddan			
Variable	< 0.5	>= 0.5 and < 1	>= 1 and < 1.5	>= 1.5
Wheat yield (kg/feddan)	2423 (N,N,N)	2463 (N,N)	2446 (N)	2591
Feddan	0.30	0.60	1.06	3.64
Total labor/feddan	44.3 (Y,Y,Y)	34.0 (Y,Y)	28.3(N)	27.9
Family labor/feddan	32.1 (Y,Y,Y)	19.1 (Y,Y)	12.6 (Y)	6.6
Hired labor/feddan	11.9 (N,Y,Y)	14.0 (N,Y)	15.5 (Y)	21.2
Fertilizer/feddan	114.5 (N,Y@10%,N)	107.8 (N,N)	101.8 (Y@10%)	125.9
Machine hours/feddan	37.4 (Y,Y,Y)	29.8 (Y,Y@10%)	26.0 (N)	25.9
Mule days/feddan	14.2 (N,Y,Y)	10.7 (Y,Y)	6.2 (Y)	3.3
Adult males/feddan	8.3 (Y,Y,Y)	4.5 (Y,Y)	2.6 (Y)	1.2
Proportion in group which received credit	0.17 (Y,N,Y)	0.26 (N,N)	0.24 (N)	0.30
Number of observations	161	233	195	199

Note: Entries in brackets refer to statistical significance of column mean with regard to columns to the right. N=Not significant, Y = significant at the 5% level or better, Y@10% = significant at the 10% level.

The Model and Estimation

The stochastic production frontier for wheat farmers is assumed to be of the Cobb-Douglas form[6]:

$$\ln(y_i) = \alpha_0 + \sum_{j=1}^{19} \alpha_j \cdot D\_GOV_{ji} + \beta_1 \cdot \ln(FEDDAN_i) + \beta_2 \cdot \ln(FAMLAB_i) + \beta_3 \cdot \ln(HIRLAB_i) + \\ \beta_4 \cdot \ln((FERT_i) + \beta_5 \cdot \ln(MACHINE_i) + \beta_6 \cdot \ln(MULE_i) + \gamma_1 \cdot DISECTS_i + \\ \gamma_2 \cdot IRRIKNOW_i + \gamma_3 \cdot DUEXVIS_i + \gamma_4 \cdot \ln(AGE_i) + \gamma_5 \ln(AGE_i)^2 + \varepsilon_i \tag{1}$$

where the i = 1,...788, denote the ith farm[7]; y is the amount of wheat harvested in kilogrammes; D_GOV are dummies for the governorates of: Damietta, Dakahlia, Sharkia, Ismailia, Qalubia, Kafr El-Sheikh, Gharbia, Menufia, Beheira, Giza, Fayum, Beni Suef, Minia, Assiut, Sohag, Qena, Aswan, New Valley; and Nubariah;[8] the inputs FEDDAN, FAMLAB, HIRLAB, FERT, MACHINE, MULE are as defined in the table 1;[9] DISECTS, and IRRIKNOW are variables that capture potential gains from improved extension services,[10] and; DUEXVIS measures the impact of extension services per se; AGE and AGE squared of the household head are proxies for farmer experience; α , β and γ denote parameters to be estimated and ε is the error term, further defined below.

The error term is ε = v – u, where v is a symmetric component assumed to be distributed independently and identically as $N(0,\sigma_v^2)$ that captures exogenous shocks, such as weather, supply shocks, and unobserved heterogeneity of households plus measurement error. The term u is a non-negative random variable that is associated with the level of technical inefficiency of production. It is assumed to be distributed independently and identically as $|N(\mu,\sigma_u^2)|$ with truncation point at 0. Equation (1) represents a stochastic frontier production

[6] A more flexible functional form did not generate sensible results presumably because of the high degree of collinearity among the regressors.
[7] 12 observations for which fertilizer consumption was zero were dropped. This also accounts for the fact that there are only 19 governorate dummies as Matruh drops out.
[8] Nubariah is not a governorate but a new agricultural land that crosses several governorates.
[9] The units used, i.e. hours for machines and days for mules, correspond to the unit most frequently reported (in an effort to minimize measurement error).
[10] I note that the overlap between IRRIKNOW and DISECTS is 16 out of 605 cases, or less than 3 percent.

function, as suggested independently by Aigner, Lovell and Schmidt (1977) and Meeusen and Van den Broeck (1977).

Single equation estimation of the production function is justified if farmers maximise expected profits and consumption and production decisions are separable (Singh, Squire and Strauss (1986)). Separability requires that all but one of the input markets are perfect. In this regard I note that in many governorates there are no or very few land market transactions: in 7 governorates there are no households renting land (in the sample) while in two cases 30 percent of operators rent-in land while in another 3 governorates between 23 and 25 percent of operators rent-in land. Overall 90 percent of wheat farmers are owner-operators. If labor markets are also imperfect then de Janvry, Fafchamps and Sadoulet (1991) have shown that household choices can be represented as a system of labor demand and supply with endogenous shadow cost of labor, w*. This leads to a set of reduced form labour and input use equations that are a function of the shadow wage, input prices of the variable inputs, semi-fixed factors of production such as tools, as well as human capital. The shadow wage can be substituted for by the variables that it is a function of, i.e. household's manpower, unearned income and all its productive assets (Fafchamps and Quisumbing (1999)).

Results

Prior to estimating equation (1) I test for non-separability by regressing total labour on a number of variables including household composition and assets. Results support the assumption of non-separability. In particular family size as well as the proportion of males and that of females in the age groups: 0- 4; 5-9; 10-17; 18-49; 50+, literacy of the head, land size and ownership of a tractor were found to be statistically significant explanatory variables.[11] As a further check I ran equation (1) without the variable inputs being instrumented but with the residuals of the first-stage reduced form equations included. On the basis of this Hausman type test the null of the variable inputs being exogenous is rejected (on the basis of an F-test). I therefore instrumented the variable inputs: family labor, hired labor, fertilizer, machine hours and mule days.

An additional reason for instrumentation is that some of the variables are likely to be measured with error. This is true for machine hours and mule days because although I used the units which were most common some observations had to be transformed by what is invariably an arbitrary factor. Table 3 also indicates measurement error specific to very small farms. Results obtained by excluding farms smaller than 0.5 feddan show that the mean, standard deviation and range of the estimated technical efficiency are virtually identical to the estimates obtained for the full sample. Finally, family and hired labor did not sum to total labor in some 40 cases. As a check I ran the final equation without these observations and found the results changed only marginally.

Equation (1) is therefore estimated using the predicted values of the endogenous variables. The adjusted R^2 for the equations for family labor, hired labor, fertilizer, machine hours and mule days are 0.49, 0.71, 0.82, 0.74 and 0.55 respectively. The following instruments are included: distance to the district capital, prices of: fertilizer, machine hour, mule day, tractors and water pump use; dummies for: ownership of carts, tractors and mules; land, literacy of head, age of head and age of head squared, number of household members, proportion of males in the following age groups: 0- 4; 5-9; 10-17; 18-49; 50+; proportion of females in the age groups as defined for males; non-earned income, dummy for light coloured soil, plus all of the exogenous variables in the production function.[12]

[11] The regression results are not reported here but are available from the author on request.
[12] Results are available from the author on request.

Results for equation (1) are given in table 4. [13] I present the Modified OLS regression results and the ML estimates for the stochastic production frontier. The Modified OLS approach was first suggested by Afriat (1972) and Richmond (1974) and consists of estimation by OLS and then shifting up the constant term by the mean of the distribution assumed for the one-sided term.

Table 4: Modified OLS and Maximum-likelihood Estimates of the Stochastic Cobb-Douglas Production Frontier for Egyptian Wheat Farmers[a]

Variable[b]	Stochastic Frontier			
	Modified OLS Dep Var = Output		MLE Dep Var = Output	
	Coef.	Robust s.e.	Coef.	Robust s.e..
CONSTANT	2.686	1.804	4.686	1.804*
ln(FEDDAN)	0.464	0.077*	0.576	0.077*
ln(FAMLAB)†	0.121	0.050*	0.135	0.050*
ln(HIRLAB)†	0.058	0.043	0.050	0.043
ln(FERT)†	0.234	0.073*	0.175	0.073*
ln(MACHINE)†	0.252	0.064*	0.204	0.064*
ln(MULE)†	-0.051	0.038	-0.035	0.038
AGE	1.401	0.947	0.683	0.947
AGE^2	-0.165	0.124	-0.069	0.124
DISECTS	-0.034	0.033	-0.035	0.033
IRRIKNOW	-0.125	0.043*	-0.140	0.043*
DUEXTVIS	0.076	0.029*	0.070	0.029*
$\ln(\sigma^2_v)$				
CONSTANT	-2.620		-2.427	0.097*
(σ^2_u)				
FEDDAN	--	--	1.346	0.338*
HIRLAB	--	--	-0.034	0.008*
FERT	--	--	-0.005	0.003*
MACHINE	--	--	-0.021	0.011
CONSTANT	-2.281	--	-2.354	0.315*
Mean Technical Efficiency	0.96		0.81	
Range of Technical Efficiency	0.81-0.99		0.30-1.00	
Log-likelihood				
Number of obs	788		788	
F(30, 757)	110			
Prob > F	0			
Adj. R-squared	0.87			

[a] The parameter estimates for the governorate dummies are not reported.
[b] Variables are defined in table 2.
*Significant at the 5% level or better.
**Significant at the 10% level.
† Denotes an endogenous variable, predicted by instrumentation.

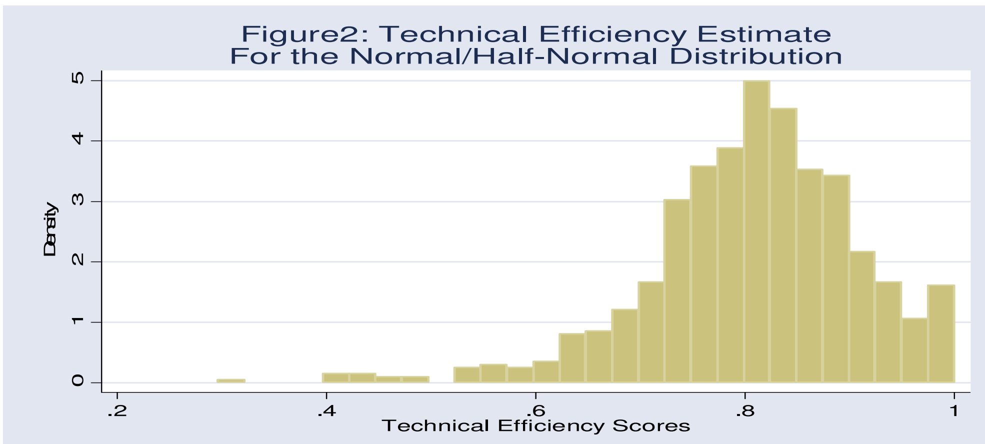
Land has the strongest impact on output. Our results show that a 10 percent increase in land-size would increase output by 5.8 percent, or a 1 feddan increase, evaluated at the mean,

[13] As already noted 12 observations for which fertilizer use was zero were dropped.

would raise output by 44 percent. Land, (apart from water) is the scarcest input and the high marginal returns to land are a reflection of the very small size of plot many farmers are constrained to cultivate. A 10 percent increase in the amount of fertilizer applied would translate into a 1.8 percent output rise. A household increasing fertilizer use from say 60 to 112 kg/feddan would increase output by about 15 percent.[14]

With regard to the variables capturing the effect of managerial ability and extension support the results suggest that increased support to improving irrigation techniques would raise output by another 14 percent. At the mean for IRRKNOW = 1 (see table 2) this would imply increased output of 344 kg/feddan, respectively. Providing extension services to farmers who reported zero or only 1 visit would raise their output by 177 kg/feddan, on average.

The estimates for technical efficiency show that on average farmers are 81 percent efficient with a range of 30 to 100 percent. Figure 2 gives the frequency distribution. 82 percent of the technical efficiency estimates are in the 70-94 percent range.



Although the estimates for technical efficiency are quite similar to those obtained when not controlling for endogeneity and measurement error they are sensitive to the assumptions made about the error term and its parameters. In particular while the frontier appears well defined when using the uninstrumented variables, this is not the case when using the instrumented variables. Rather, in the latter case the variance of the one-sided term tends to zero. This would explain the result of 96 percent average technical efficiency and narrow spread for the MOLS estimates. The problem is resolved when the presence of heteroscedasticity in u is incorporated in the model. Heteroscedasticity in u leads to biased estimates of the parameters of the production frontier and technical efficiency.[15] Results show that the variance is directly related to farm size and inversely to total labor, fertilizer use and

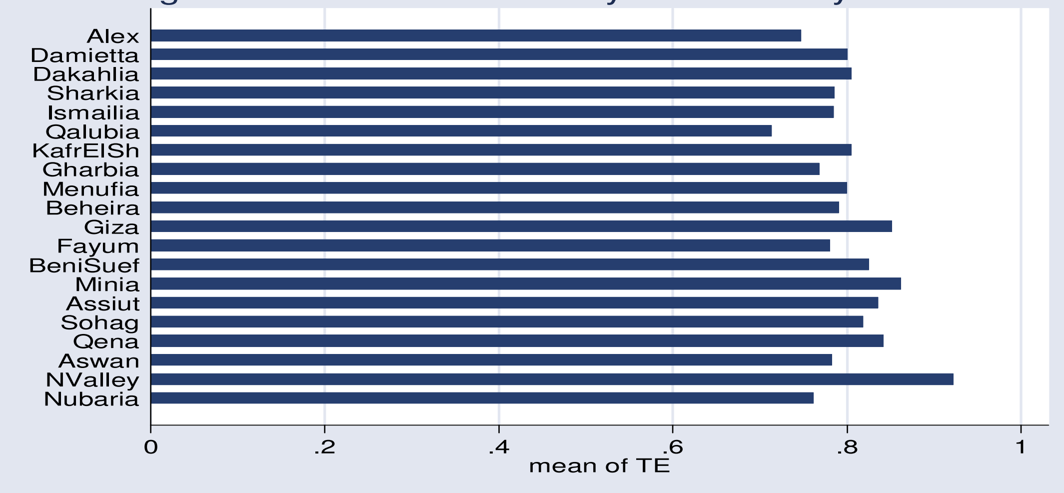
[14] Results for the various education variables that are available suggest that these capture a wealth effect rather than the effect of education. I note that credit availability was not found to be significant in the preliminary regressions and was not included in the final specification.

[15] Caudill and Ford (1993) show that heteroscedasticity in the one-sided error in the Cobb-Douglas stochastic frontier production function leads to overestimation of the intercept and underestimation of the slope coefficients. Caudill, Ford and Gropper (1995) observed that residuals are sensitive to specification errors, particularly in frontier models, and that this sensitivity is passed on to the ineficiency measures.

machine hours. The estimate of average technical efficiency is robust to the number of variables included, i.e. it does not drop below 81 percent once the key variables are accounted for.

Across governorates the measure of technical efficiency varies between 71 and 92 percent (see figure 3). At the bottom end average technical efficiency is estimated as 71, 74 and 76 percent for Qalubia, Alexandria and Nubaria, respectively. At the top end we have 92, 86 and 85 for New Valley, Minia and Giza, respectively. Average technical efficiency by farm size, as defined in table 3, ranges between 80 and 81 percent, i.e. there is no difference across farm size. This result is in line with Moussa and Jones (1991) who, using the approach developed by Lau and Yotopoulos (1971), did not find a difference in relative economic efficiency between large and small farms (with a cut-off point at 3 feddan).

Figure 3. Technical Efficiency Estimates by Governorate



Conclusion

Using the Egyptian Wheat Sample Survey for 800 farmers for 1998 a Cobb-Douglas frontier production function is estimated under the assumption of non-separability of production and consumption decisions. The estimates are sensitive to the distributional assumptions imposed and our results are corrected for heteroscedasticity. The estimated average level of technical efficiency is 81 percent with a range of 30 to 100 percent. 82 percent of farms achieved between 70 and 94 percent technical efficiency. Mean technical efficiency at the governorate level ranged from 92 percent for New Valley to 71 percent for Qalubia. I did not find evidence that technical efficiency estimates varied by farm size or variables that capture the impact of extension services. However extension services and, in particular, improved knowledge of irrigation were found raise output, the latter by up to 14 percent.

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Agricultural and Development Economics Division (ESA)
The Food and Agriculture Organization
Viale delle Terme di Caracalla
00100 Rome
Italy

Contact:
Office of the Director
Telephone: +39 06 57054358
Facsimile: + 39 06 57055522
Website: www.fao.org/es/esa
e-mail: ESA@fao.org