ECONOMIC EFFICIENCY OF CROP PRODUCTION IN EGYPT

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Abstract

Despite positive agricultural developments over the period 1980–2007, significant increases in cultivated area are not expected, given scarce water resources and limited technology. With this in mind, the study sets out to explore prospects for better usage and allocation of existing limited resources by assessing the technical, allocative and economic efficiency of crop production in Egypt at the governorate level and by region. A non-parametric frontier model (DEA) is used to estimate the efficiency of Egyptian crop production at the farm and village levels using data of the Agricultural Farm Income Survey (AFIS) for 2003/2004. On average, the results suggest that the sector suffers from serious allocative and technical inefficiencies, which if resolved crop production could exceed by 45 percent the level achieved in 2003/2004. The study also tries to identify the determinants of efficiency, which are useful in guiding extension activities, research and technical support.

ملخص

على الرغم من التطورات الإيجابية التي شهدها قطاع الزراعة في مصر خلال الفترة ١٩٨٠-٢٠٠٧، فمن غير المتوقع حدوث زيادات ملموسة في المساحة الزراعية نظرا لندرة المياه وضعف الفنون التكنولوجية. وفي هذا الإطار، تبحث الدراسة سبل تحسين استغلال وتخصيص الموارد المحدودة المتاحة، وذلك من خلال تقدير مستويات الكفاءة الفنية والتخصيصية والاقتصادية في مصر على مستوى المحافظة وبحسب المنطقة. وتعتمد الدراسة في ذلك على نموذج لامعلمي لحدود الإنتاج (وهو التحليل التطويقي للبيانات) لتقدير كفاءة إنتاج المحاصيل في مصر على مستويي كل من المزرعة والقرية باستخدام بيانات مسح الدخل المزرعي الزراعي لعام ٢٠٠٣/٢٠٠٤. وفي المتوسط، تشير النتائج إلى أن قطاع الزراعة يعاني من أوجه قصور شديدة من حيث الكفاءة الفنية والتخصيصية، والتي في حالة معالجتها يمكن أن يشهد إنتاج المحاصيل في مصر زيادة تتجاوز ٤٥% من المستوى المتحقق في عام ٢٠٠٣/٢٠٠٤. كما تحاول الدراسة إلقاء الضوء على محددات الكفاءة، الأمر الذي يعد ذا فائدة لأنشطة الإرشاد الزراعي والبحوث والدعم الفني.

1. INTRODUCTION

Over the period 1980-2007, crop production in Egypt increased in terms of *cultivated area*, which rose by 44 percent from 5.87 million feddans in 1980 to around 8.44 million feddans in 2007. Cropped area increased as well from 11.1 million feddans in 1980 to reach 15.4 million feddans in 2007—an increase of approximately 39 percent (MALR 2009). However, due to increasing water scarcity enlargement of the cultivated area is not likely to continue at significantly high rates.

The *cropping pattern* evolved towards more *diversification*. Contribution of fruits and vegetables to agricultural production, particularly in newly reclaimed lands, increased at the expense of traditional field crops. Cropped area of fruits and vegetables rose from 3.1 and 9.3 percent in 1980 to 8.5 and 13.1 percent respectively in 2007, while the area of field crops receded from 87.6 to 78.3 percent. These developments have been accompanied by significant improvements in *land productivity* of most important crops, particularly grains and sugar crops.[1] Meanwhile, yields per feddan of berseem, cotton and oil plants stagnated, leading to significant loss of relative importance. Land productivity of vegetable crops showed an impressive growth as a result of improving irrigation and fertilizer application technologies. Yields of fruit crops also increased, quality improved and supply duration lengthened (MALR 2009).

Despite these generally positive developments, and in view of increased water scarcity, significant increases in cultivated area (horizontal extension) are not expected. Prospects for significant land yield increases (vertical extension), given the prevailing technologies, are also limited. However, better use and allocation of limited agricultural resources to various agricultural crops may enhance agricultural production through improved economic efficiency. This study attempts to assess the *economic efficiency* of crop production in Egypt at the governorate level and by region. It also tries to identify the determinants of efficiency which are useful in guiding extension activities, research and technical support.

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[1] For wheat, yields have doubled from 1.36 to 2.72 tons per feddan between 1980 and 2007; for rice, yields rose by 67 percent over the same period, in addition to the introduction of short duration varieties which decreased water consumption of this crop by 25 percent; for maize, yields rose by around 90 percent. For sugar cane, yields increased by 44 percent, reaching the highest levels worldwide; for sugar beets, yields rose by 80 percent from 1980 to 2007.

Economic efficiency refers to the maximum output attainable from using several inputs. It has two components. The purely *technical* or physical component refers to the ability to avoid waste by producing as much output as input usage allows, or by using as little input as output production requires. Thus the analysis of technical efficiency can have an output-augmenting orientation or an input-reducing orientation. The *allocative* or price component refers to the ability to combine inputs and outputs in optimal proportions in light of prevailing prices (Lovell 1993). Economic efficiency of Egyptian crop production at the governorate and region levels is estimated using the database constructed on the basis of the Agricultural Farm Income Survey (AFIS) for 2003/2004[2] conducted by the Ministry of Agriculture and Land Reclamation. The degree of underutilization and overutilization of major agricultural inputs is also assessed. Finally, through regression analysis the study identifies major factors influencing economic efficiency.

The paper consists of five sections. Following the introduction, Section 2 addresses the methodology of estimating economic efficiency of crop production in Egypt. Section 3 presents the database and data treatment. Section 4 presents the results of estimation. It also discusses the degree of underutilization/overutilization of agricultural inputs and identifies the determinants of economic efficiency. Section 5 concludes.

2. METHODOLOGY FOR ASSESSING ECONOMIC EFFICIENCY

Economic efficiency refers to the maximum output (or index of outputs) attainable from using several inputs as depicted by the production function. Another representation of economic efficiency shows the minimum expenditure for the production of an output, given input prices, as reflected by the cost function. A third representation identifies the combination of inputs that maximize profits, given output and input prices, as shown by the profit function. These three functions are typical frontiers that characterize optimizing behavior of an efficient producer and establish limits of their dependent variables (Forsund, Lovell and Schmidt 1980).

Frontiers have been estimated over the past 50 years using many different methods. The two principal methods are data envelopment analysis (DEA) and stochastic frontiers involving respectively mathematical programming and econometric methods. The discussion in this

[2] The agricultural year starts in October and ends in September.

section provides a brief overview of modern efficiency measurement, followed by a description of the data envelopment analysis used to assess various efficiencies.

2.1. Modern Efficiency Measurement

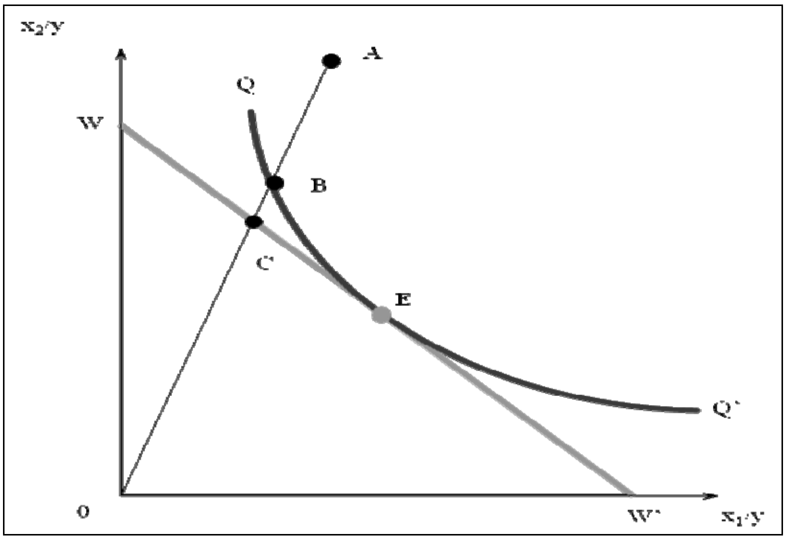
Two sets of measures have been devised. The first addresses the question: by how much can input quantities be reduced without changing the output quantities produced? These are *input-oriented* measures. Alternatively, the second set answers the question: by how much can output quantities be proportionally expanded without altering the input quantities used? These are *output-oriented* measures. The choice of one or the other set of measures depends on whether the decision making unit has more control over inputs or outputs. In the case of the Egyptian farmer, it is more likely that he is in control of inputs used rather than on outputs produced. Thus the input-oriented measures are more appropriate.

Modern efficiency measures begin with Farrell (1957) who defines a simple measure of firm (farm in our case) efficiency that uses multiple inputs. Adopting an input-oriented approach, he asserts that efficiency consists of two components: *technical efficiency* which reflects the ability of a firm to obtain maximum output from a given set of inputs and *allocative* (price) *efficiency* which expresses the ability of a firm to use the inputs in optimal proportions[3] given their respective prices. These two measures are then combined to give a measure of total *economic* (overall) *efficiency*. Farrell illustrates his definitions referring to a simple example of a farm producing a single output (y) using two inputs (x_1, x_2) under the assumption of constant returns to scale.[4] Knowledge of the unit isoquant of the fully efficient farm depicted by QQ' in Figure 1 permits the measurement of technical efficiency.

[3] Optimal proportions refer to the input mix used in such a way as to equate the marginal product of a pound spent on input 1 to the marginal product of a pound spent on input 2 and so on for all inputs used.

[4] This assumption allows representing the technology using an isoquant corresponding to producing one unit of output.

Figure 1. Input-Oriented Measures of Technical and Allocative Efficiencies



If a given farm uses quantities of inputs defined by point A, to produce a unit of output, the technical inefficiency of that farm could be represented by the distance BA, which is the amount by which all inputs could be proportionally reduced without a reduction in output. This is usually expressed in percentage terms by the ratio BA/OB which shows the percentage by which all inputs could be reduced without changing output. *Technical efficiency* (TE) of a farm is most commonly measured by the ratio:

$$TE = OB/OA$$

i.e., the ratio of inputs needed to produce the most efficient production as regards input use (situated on the isoquant QQ') to the inputs actually used to produce this unit of output. Note that this is equal to 1- BA/OB, BA/OB being the ratio of technical inefficiency. TE will take a value between zero and 1; zero when the ratio of technical inefficiency is 1, and 1 when the degree of inefficiency is zero, i.e., if the farm is technically fully efficient with A coinciding with B on the isoquant.

If the input price ratio represented by the isocost line WW' in Figure 1 is also known, a fully efficient farm would operate at point E. *Allocative efficiency* (AE) may be calculated for the farm operating at A by the ratio:

$$AE = OC/OB$$

Note that CB represents the reduction in costs of production that may occur if production were achieved at the fully efficient (allocatively and technically efficient) point E instead of at the technically efficient, but allocatively inefficient point B.

Total *economic efficiency* (EE) is defined by the ratio EE = OC/OA where the distance CA is the cost reduction if production is achieved at a technically and allocatively efficient level E. Note that all three measures TE, AE, and EE fall within the range zero and 1 and that *the product of technical TE and allocative AE efficiencies equals the overall economic efficiency EE.*

Farrell further discussed the extension of his approach to accommodate more than two inputs, multiple outputs and non-constant returns to scale. A more detailed treatment of modern efficiency measurements may also be found in Lovell (1993) (see also Fare and Lovell 1978).

Finally, note that the production function of the fully efficient firm (farm) represented by the isoquant QQ' is not known in practice. It must be estimated from observations on a sample of firms (farms) in the activity concerned (agricultural crop production). In this paper we use data envelopment analysis (DEA) to estimate this frontier (Coelli 1996).

2.2. Data Envelopment Analysis (DEA)

This section presents a brief non-technical discussion of DEA as a non-parametric mathematical programming approach to frontier estimation. The DEA algorithm can measure three empirically-derived concepts related to production economics with reduced computational effort and time. The DEA method, first proposed by Charnes, Cooper and Rhodes (1978) was based on a model which had an input orientation and assumed constant returns to scale (CRS). This method has been widely used for measuring the decision-making performance of private and public entities. The method has become a cornerstone of modern efficiency analysis because it is exceptionally appropriate to many decision-making issues.[5]

In order to obtain the three efficiency indicators, information on output and input quantities and prices is required. Moreover, one should consider a behavioral objective such as the farms are seeking cost minimization. First, the technical efficiency (θ) can be found by solving the following mathematical problem:

[5] For a review of DEA contributions, history, models and interpretation see Seiford (1996), Cooper, Seiford and Zhu (2004) and Cooper, Seiford and Tone (2007).

$$\min_{\theta,\lambda} \theta$$

Subject to
$$-y_i + Y\lambda \geq 0,$$
$$\theta x_i - X\lambda \geq 0, \quad (1)$$
$$\lambda \geq 0,$$

where θ is a scalar, λ is a N×1 vector of constants, X is a K × N input matrix, Y a M × N output matrix. For the i[th] decision making unit (DMU) inputs and outputs are represented by the vectors x_i and y_i, respectively. Moreover, K represents the number of inputs; M is the number of outputs and N the number of DMUs. In our case K may vary from 5 to 8 inputs depending on its categorization into land, labor (that is in some cases disaggregated into household and hired labor), machines, animal labor, and other currently purchased inputs (fertilizers, pesticides and seeds that are sometimes included separately or as one aggregate purchased inputs), M is represented by one Fisher output index as a combination of various crops and N equals 2422 farms. The value of obtained θ will be the technical efficiency score for the i[th] DMU. It satisfies $\theta \leq 1$, with a value of 1 indicating a point on the frontier and hence a technically efficient farm, according to Farrell (1957) definition. Note that the linear programming problem is solved N times, once for each DMU (farm) in the sample. A value of θ is thus obtained for each one of the 2422 farms in the sample. Thereafter, a geometric mean is calculated in order to aggregate at the governorate, regional and national levels.

Second, in order to obtain the allocative efficiency one would then run a cost minimization DEA as follows:

$$\min_{\lambda,x_i^*} w_i' x_i^*$$

Subject to
$$-y_i + Y\lambda \geq 0,$$
$$x_i^* - X\lambda \geq 0, \quad (2)$$
$$N1'\lambda = 1,$$
$$\lambda \geq 0,$$

where w_i is a vector of input prices for the i^th^ DMU, x_i^* is the cost minimizing vector of input quantities calculated in the linear programming problem given input prices w_i and output levels y_i and $N1$ is a N×1 vector of ones. Hence the total economic efficiency of the i^{th} farm would be calculated as $w_i' x_i^* / w_i' x_i$, which is the ratio of minimum cost to observed cost. Subsequently, one can calculate the allocative efficiency as the ratio between economic and technical efficiencies as mentioned in the previous sub-section.

3. Data Used and Measurement of the Main Variables

3.1. Data Description

The analysis of this paper relies on the 2003/2004 Agricultural Farm Income Survey (AFIS) conducted by MARL (Ministry of Agriculture and Land Reclamation). AFIS is based on a stratified multistage random sample, representative of different agriculture landholding sizes in Egypt. The sample is composed of 4216 farms drawn from 19 governorates covering 219 villages in 57 districts. According to MARL classification, the sample covers Alexandria, El-Beheira, El-Gharbia, El-Menufia, Kafr El-Sheikh, El-Dakahlia, El-Sharkia, El-Ismailia, Matruh, and North Sinai governorates from Lower Egypt and Assiut, Aswan, Beni-Suef, El-Fayoum, Luxor, El-Menya, New Valley, Sohag, and Qena as Upper Egypt. However, for the purpose of this paper the governorates are reorganized into five regions i) Alexandria as *Metropolitan*; ii) El-Beheira, El-Gharbia, El-Menufia, Kafr El-Sheikh, El-Dakahlia, El-Sharkia, and El-Ismailia as *Lower Egypt* governorates; iii) *Middle Egypt* encompassing the governorates of Beni-Suef, El-Fayoum, and El-Menya; iv) Assiut, Sohag, Qena, Aswan and Luxor as *Upper Egypt*; and v) the *Border* governorates including Matruh, North Sinai and New Valley. After reorganization, each of the five previous regions includes 137, 1726, 715, 978 and 660 farms, where the number of crops in each region is successively 24, 46, 37, 37 and 31 (see Table 1).

Some of the farms are involved in both plant and animal production. The focus of this paper will be on plant production. AFIS comprises 85 crops that are cultivated on seasonal and permanent basis. Seasonal crops comprise three different cropping seasons: winter, summer and Nili; permanent crops include such crops as sugar cane, dates, citrus and mango. All crops may be further categorized into traditional and non-traditional. The first group is classified into fodder (berseem and yellow corn or summer maize) and non-fodder (barley, horse beans, cotton, summer and nili maize, rice, wheat, …), the second is composed of fruits (including citrus), vegetables, and aromatic, medicinal and oil plants (AMO) (Kheir-El-Din and El-Laithy 2008).Table 1 highlights the number of traditional and non-traditional crops grown in each region.

Table 1. Distribution of Crops by Region

Crops / Region	Non-traditional			Traditional		Total
	Fruits	Vegetables	AMO	Fodder	Non-fodder	
Metropolitan	4	12	0	2	6	24
Lower Egypt	11	16	3	3	13	46
Middle Egypt	8	10	6	5	8	37
Upper Egypt	8	9	6	5	9	37
Border	16	4	1	4	6	31

Source: Authors' calculations based on AFIS.

Egyptian agriculture in *old lands* is characterized by small landholdings and is classified by MARL into four categories: extra small (less than one feddan), small (one to three feddans), medium (three to less than five feddans) and large (five and above).

The distribution of farms by size of landholdings differs significantly between Lower, Middle and Upper Egypt, and further between Metropolitan and Border governorates as indicated in Table 2.

Landholdings in Metropolitan governorates (Alexandria) appear according to AFIS to be more concentrated in large landholdings, exceeding five feddans (51.1 percent), the same applies to Border governorates (56.7 percent). Landholdings appear to be more evenly distributed among various sizes in Lower Egypt, with a tendency towards more concentration in extra small and small landholdings (74.1 percent). In contrast to the previous regions, extra small landholdings account for more than 40.1 percent of the total number of farms in Middle Egypt and 50.2 percent in Upper Egypt. Both extra small and small landholdings represent around 81.7 percent of farms in Middle Egypt and more than 83.1 percent of farms in Upper Egypt. The majority of farmers with extra small landholdings practice subsistence agriculture but nevertheless direct a larger portion of their output to local markets (92.8 percent on average as indicated in AFIS). This suggests that although directing a portion of their outputs to own consumption, farmers with extra small land holdings should be concerned with cost and profit calculus as the larger portion of their outputs is sold on the market.

Table 2. Distribution of Farms by Size and Region

Size of farms / Region	Extra small	Small	Medium	Large	Total
	< One feddan	1 to < 3	3 to < 5	5 and more	
Metropolitan	7.30	22.63	18.97	51.10	100.00
Lower Egypt	36.61	37.49	11.01	14.89	100.00
Middle Egypt	40.14	41.54	10.63	7.69	100.00
Upper Egypt	50.20	32.82	8.59	8.39	100.00
Border	8.48	18.94	15.91	56.67	100.00

Source: Calculated by the authors from AFIS 2003/2004.

3.2. Construction of the Main Variables

Crop level data from the 2003-04 AFIS were used to estimate production frontiers. The crops consisted of permanent plants comprising apricots, bananas, dates, figs, grapes, guavas, citrus including limes, mandarins and oranges, mango, peaches, pomegranates, olives, and sugarcane. The vector of crops used also encompassed wheat, maize, fodder maize, barley, berseem, lupine, rice, sesame, cotton and sorghum together with their by-products. Moreover, beet, green peas, molokhia, sugar beet, dry and green beans, horse beans, cantaloupe, eggplant, flax, green peas, lettuce, onion, peanuts, potatoes, tomatoes, watermelon, and zucchini were also taken into consideration. Aggregate crop (agricultural plant) output at the farm level was represented by a quantity index. The most appropriate indicator for that purpose is the Fisher output index given the nature of the data that contains many zero values. The Fisher index is calculated as follows:

$$FQ_{0,1} = \sqrt{\frac{\sum_{i=1}^{N} p_0^i q_1^i}{\sum_{i=1}^{N} p_0^i q_0^i} \cdot \frac{\sum_{i=1}^{N} p_1^i q_1^i}{\sum_{i=1}^{N} p_1^i q_0^i}} \quad (3)$$

Where *FQ* is the Fisher output index for a given farm, q^i_j is the total quantity produced of a crop *i* at the national or farm levels j taking the values zero and one, respectively. And p^i_j, is the market price of crop *i* at the *j* level (0 for the national level and 1 for the farm level). A caveat that should be made at this point is that 65 crops were taken at the national level while the number of crops represented in each region is 48 and 45 crops in Lower and Upper Egypt,[6] respectively. The 48 crops taken into consideration in Lower Egypt represent on

[6] Lower and Upper Egypt are as defined in AFIS.

average 95.7 percent of total plant production in that region, whereas the 45 crops of Upper Egypt correspond to an average of 97.7 percent of total regional plant production.

Turning to inputs used in the production process, five to eight different input quantity and price indices were constructed for land as area dedicated to cropping; labor (composed of household labor and hired labor including permanent and temporary wage workers); machines; animal labor, and other purchased current inputs (composed of fertilizers, pesticides and seeds). The indices and aggregation process are briefly outlined below.

The *land* quantity input is defined as the area in kirat[7] cultivated under each crop. In order to determine the land price, the land rental price per kirat is calculated from the feddan rental price given in AFIS. This value is added to a land tax in order to determine the kirat input price. However, AFIS does not display land tax separately, it includes it instead in total tax charged to the farm. Hence, the land tax is calculated as the ratio between the total tax and the land input quantity. This is subsequently added to the kirat rental price attributed to the share of crops taken into consideration in the output index.

Turning to the *labor* input, AFIS contains information on household agriculture workdays, hired labor workdays and their daily wage rates for each type of crop. However, information on permanent workers is given at the farm level, hence not allocated between plant and animal production. Moreover, AFIS records the number of permanent workers per month and the corresponding monthly wage rate, and classifies it into four categories: keepers, guards, workers and others. Given this information, the labor input is an aggregation of the three types of labor. Starting with hired labor, quantities and wages for the farm are constructed using the number of workdays and daily wage rates for temporarily hired workers.

AFIS does not include information on the household daily wage rates. Instead the average village daily wage prevalent by crop and taking account of male, female and child discrepancy has been used. Subsequently, the aggregation procedure of temporary and household worker follows the same equation. We start by calculating the daily farm wage for those types of labor computed as weighted average daily wage of males, females and children

[7] The feddan is the unit of measurement of agricultural land. It measures about 4200 square meters and comprises 24 kirats. Hence the kirat measures around 175 square meters.

working on the crops under consideration using their relevant costs as weights. This may be represented by the following equation:

$$DWR_l = \sum_{i=1}^{N} \sum_{g=1}^{3} w_{ig_l} \frac{d_{ig_l} w_{ig_l}}{\sum_i \sum_g d_{ig_l} w_{ig_l}} \qquad for\ l = hired, household \qquad (4)$$

where DWR_l is the daily wage rate, l is the type of labor hired or household, i is the crop type, g is the gender of the worker: male, female or child, w_{igl} is the number of days worked on each crop by worker classification and type, and d_{igl} is the daily wage in each crop by worker classification and type. The quantity of workdays is then computed by dividing the cost of labor by DWR_l.

As mentioned above the information on permanent labor has two different aspects. First, the quantity of labor used and wages are on a monthly basis; they have been transformed into number of working days and daily wages. They have been subsequently used to calculate the weighted average daily wage and the imputed number of permanent labor workdays. Second, the four categories of permanent labor are reported at the farm level. Hence, it is important to only incorporate the portion of the input quantity and price that corresponds to the crop shares included into the Fisher output index. To do that those items are first distributed between farm plant and animal production activities according to the share of variable costs incurred in each activity.[8] Then the share of crops in the input quantity and wages of permanent labor are taken from the former portion of activity. At that end, the labor input quantity and price are the sum of the quantity of workdays and the daily wage rates of temporary, permanent and household labor sketched above. Alternatively, two sets of labor input quantity and price have been estimated: one for *household labor* inputs and the other for *hired labor* inputs representing the quantity of workdays and the daily wage rates of temporary and permanent labor, as previously explained.

AFIS *machines* variable and capital expenditures are available by crop and on the farm level, respectively. Spending on income tax, interest on loans and general expenses as elements of capital cost have been disregarded. As for the machine variable cost, the information on hours for different machines used by farmers in cultivation of each crop as

[8] Variable costs in plant production are taken to include expenditure on fertilizers, seeds, hired labor, animal labor and machinery; and for animal production it includes animal fodder and hired labor.

well as hourly rental rates together with the oil and fuel quantities and prices are used to calculate the weighted average of machinery prices and the total number of machine hours devoted to crop production by farm.

Animal labor input cost is the sum of rental costs for all types of animals. It must be noted that there is no information whether the animals used in agriculture are owned by farmers or rented from others. Nonetheless, the survey reports the number of workdays of different animals for each crop along with rental rates. A rental rate for animal labor is computed as weighted average of daily animal wage rates, using cost shares as weights in the formula. The imputed quantity of animal labor, i.e., the number of animal workdays per farm is calculated by dividing total animal cost by the computed daily rental rate.

Finally, indices of *purchased current inputs* price and quantity are calculated. They incorporate purchased *fertilizers, pesticides and seeds*. The average input price is calculated for each of the three inputs as the weighted average input price applied to each crop taken into consideration, using relevant costs as weights. Each input quantity is then computed through dividing the sum of values of each input used for each crop by the weighted input price. The purchased input quantity and price are respectively the sums of quantity and price of fertilizers, pesticides and seeds explained above.

Selection of farms for the DEA analysis was on the basis of plant production that exceeds 75 percent of total variable cost. This means that farms producing only animals and/or have a mixture of animal and plant production with a fodder cost share of more than 75 percent of the cost of plant production were excluded from the analysis. This restricted the total sub-sample used for the DEA analysis to 1293 and 1129 farms from Lower and Upper Egypt, respectively as classified by AFIS, a total of 2422 farms from a total of 4216 farms covered by the survey.

4. Estimation Results

The following section presents the results of estimation of economic efficiency; it discusses technical and allocative efficiencies and then assesses the degree of over/underutilization of various groups of inputs. It then ends with identification of main determinants of various components of economic efficiency.

4.1. Economic Efficiency of Crop Production

Economic efficiency indices have been calculated under the assumption of constant returns to scale. Farm and village level (213 villages) efficiencies have been estimated. The former is used in the estimation results presented in the next subsection. The latter have been aggregated using the geometric means for resulting efficiency indices calculated at the governorate, region and country levels.

The geometric mean of economic efficiency indices for all regions was 0.424. Metropolitan and Lower Egypt governorates means were higher than the national mean. Middle and Upper Egypt regions as well as Border governorates had lower economic efficiencies than the national mean. Results for the first two regions were mainly driven by indices of allocative efficiencies which were consistently higher than their respective technical efficiency indices in all governorates considered. In the relatively lagging regions, in terms of economic efficiency, of the south and the borders, allocative efficiency indicators were persistently lower than indices of technical efficiency in all governorates with the exception of four out of eleven governorates considered, namely El-Menya, Assiut, Sohag and Luxor where allocative efficiency indices were higher (Table 3).

4.1.1. Technical efficiency

At the national level, technical efficiency, as shown in Table 3 reaches 0.686. This means that the consumption of all inputs could be reduced by 31.4 percent without reducing output. Border and metropolitan regions with technical efficiency indices of 0.790 and 0.757 successively, have higher technical efficiency than the national mean. They are followed by Upper (0.685), Lower (0.620) and Middle (0.616) Egypt. These results indicate that border governorates could reduce inputs used by 21.0 percent without reducing output, while metropolitan areas could proportionally reduce all inputs by 24.3 percent without reducing output. The less technically efficient regions of Upper, Lower and Middle Egypt could in turn reduce inputs used by 31.5 percent, 38.0 percent and 38.4 percent successively without changing the output produced. At the governorate level, border governorates of Matruh and North Sinai have higher technical efficiency than the national mean.

Table 3. Technical, Allocative and Economic Efficiency Indices and Output Indices at Governorate, Regional and National Levels for the Agricultural Year 2003/04.

Governorates/	Efficiency index			Output index†		
Region	Technical	Allocative	Economic	Observed	Frontier‡	Difference (%)
Alexandria	0.757	0.788	0.597	7.106	9.383	32.033
Metropolitan	**0.757**	**0.788**	**0.597**	**7.106**	**9.383**	**32.033**
El-Beheira	0.668	0.798	0.533	11.211	16.777	49.644
El-Gharbia	0.584	0.787	0.460	2.540	4.349	71.188
El-Menufia	0.670	0.764	0.512	4.171	6.225	49.238
Kafr El-Sheikh	0.552	0.854	0.476	7.245	13.124	81.149
El-Dakahlia	0.589	0.862	0.507	4.540	7.712	69.883
El-Sharkia	0.706	0.724	0.511	5.977	8.461	41.547
El-Ismailia	0.572	0.780	0.446	4.714	8.241	74.802
Lower	**0.620**	**0.796**	**0.492**	**40.400**	**65.135**	**61.227**
Beni Suef	0.642	0.636	0.398	5.502	8.571	55.785
El-Fayoum	0.600	0.430	0.258	6.058	10.097	66.667
El-Menya	0.605	0.693	0.416	4.098	6.776	65.359
Middle	**0.616**	**0.587**	**0.358**	**15.658**	**25.437**	**62.456**
Assiut	0.557	0.736	0.410	3.944	7.084	79.588
Sohag	0.614	0.676	0.432	2.895	4.712	62.766
Qena	0.883	0.468	0.413	2.932	3.322	13.302
Aswan	0.780	0.467	0.356	9.124	11.693	28.145
Luxor	0.590	0.743	0.439	1.242	2.107	69.596
Upper	**0.685**	**0.618**	**0.410**	**20.138**	**29.409**	**46.036**
Matruh	0.906	0.439	0.403	4.254	4.696	10.391
North Sinai	0.804	0.616	0.485	6.716	8.352	24.363
New Valley	0.660	0.206	0.137	5.728	8.672	51.406
Border	**0.790**	**0.420**	**0.342**	**16.698**	**21.133**	**26.559**
National mean	**0.686**	**0.639**	**0.424**	**100.000**	**145.773**	**45.773**

† Performance indices were calculated using Fisher's formula.

‡ Calculated as observed output index / technical efficiency index.

Also exceeding the national mean in technical efficiency are the governorates of Qena and Aswan in Upper Egypt. The most technically efficient governorate is Matruh (0.906), it could produce the same output using 9.4 percent less inputs. The least technically efficient governorate of Kafr El-Sheikh (0.552) could produce the same output using 44.8 percent less inputs.

Given the technical efficiency indices of Table 3 and calculating the production frontier, it is possible to estimate what crop production might have been if all producers used efficiently all inputs available. The DEA model suggests that national crop production in 2003/04 could have been 45.8 percent higher; but again the range of possible efficiency gains displayed substantial spatial variations. More specifically, Border governorates could have produced 26.6 percent more output and the least technically efficient region of Middle Egypt could have boosted output by 62.5 percent. At the governorate level, the most technically efficient governorates of Matruh and Qena could have boosted output by 10.4 percent and 13.3 percent, successively. Whereas, the least technically efficient governorates of Kafr El-Sheikh and Assiut could have achieved output gains of up to 81.1 percent and 79.6 percent respectively.

4.1.2. Allocative efficiency

The allocative efficiency indices in Table 3 show inefficiency in almost all regions of the country. The national mean of AE (0.639) falls slightly below that of technical efficiency (0.686). *Border governorates* (0.420), *Middle* (0.587) and *Upper* (0.618) *Egypt* are allocatively less efficient than the national mean, unlike *Metropolitan* (0.788) and *Lower* (0.796) *Egypt* which are allocatively more efficient than the national mean.

Other indicators of allocative efficiency related to input over- or underutilization have also been calculated, maintaining the same level of output. Using DEA, *the optimal input mix which minimizes cost by governorate was calculated and compared to the observed actual input mix by governorate*. Then a Likert scale indicator was built attributing a zero value to cases where the deviation of actual input mix from the optimal cost minimizing input mix reached up to +/- 25 percent. A value of -1 was attributed to cases where the deviation of actual input mix from the optimum exceeded -25 percent of actual input mix (overutilization) and a value of 1 to cases where this percentage deviation exceeded 25 percent (underutilization). Regional and national averages were assessed according to a different Likert scale (LSI) as follows: $LSI<-0.75$ indicating strong overutilization; $-0.75 \leq LSI <-0.50$ moderate overutilization; $-0.50 \leq LSI<-0.25$ weak overutilization; correct use if $-0.25 \leq LSI \leq 0.25$; weak underutilization if $0.25<LSI\leq 0.50$; moderate underutilization if $0.5<LSI\leq 0.75$; and if $0.75<LSI$, this would indicate strong underutilization (Vicente 2004).

As observed from Table 4, at the national level the Likert scale indicators show moderate overutilization of land and machine inputs, weak overutilization of labor and seeds inputs, and correct use of all other inputs (animal labor, fertilizer and pesticide inputs). These results are portraying higher relative prices of inputs which appear to be overutilized. Alternatively, overutilized inputs appear to be used in quantities higher than optimally required, given their prevailing relative prices. This further implies that the actual marginal productivity of a pound spent on overutilized inputs is below that spent on inputs used in the right proportions or appearing to be underutilized. Further disaggregation of labor inputs into household labor and hired labor reflects weak overutilization of both labor components at the national level. However, the results differ among regions as well as among governorates.

In *Metropolitan governorates* (Alexandria) land and fertilizers are used in the right proportions; machine, animal labor and pesticides are strongly overutilized while labor inputs and seeds are strongly underutilized. Household labor is strongly underutilized[9] whereas hired labor is correctly used. In *Lower Egypt*, land, labor and seeds are used in the correct proportion to the level of output. There is weak overutilization of fertilizers, moderate overutilization of animal labor, and strong overutilization of machine work and pesticides. Differentiating between household and hired labor shows that the former is in correct use while the latter is weakly overutilized, mainly due to overutilization of hired labor in El-Gharbia, Kafr El-Sheikh and El-Sharkia. *Middle and Upper Egypt* show a similar pattern of input misallocation although different from that in other regions. They tend to strongly overutilize land, labor and seeds. They weakly overutilize (Middle Egypt) or correctly (Upper Egypt) utilize machine inputs; weakly underutilize (Middle Egypt) or correctly utilize (Upper Egypt) fertilizer inputs; and finally strongly underutilize animal labor and pesticides. *Border* governorates show moderate to weak overutilization of land, labor, machine and pesticides inputs, correct use of animal inputs, and weak underutilization of fertilizers and seeds. In all governorates of the last three regions, with the exception of the New-Valley, all governorates strongly overutilize household labor. As to hired labor, it is either strongly overutilized in all governorates of Middle Egypt or in some governorates where it is in correct use (in Upper Egypt and the Border region).

[9] This may reflect the reluctance of household members to engage in farming activities.

Table 4. Likert-Scale Indicators of Input Under/Overutilization at the Governorate, Regional and National Levels for the Agricultural Year 2003/04

	Input†								
	Land	Machine	Animal	Fertilizer	Pesticide	Seed	Labor	*HH labor*	*Hired labor*
Alexandria	0	-1	-1	0	-1	1	1	*1*	*0*
Metropolitan (avg)	**0**	**-1**	**-1**	**0**	**-1**	**1**	**1**	***1***	***0***
El-Beheira	0	-1	1	-1	-1	-1	0	*0*	*0*
El-Gharbia	0	-1	-1	0	-1	-1	0	*0*	*-1*
El-Menufia	0	0	-1	0	-1	1	0	*0*	*0*
Kafr El-Sheikh	-1	-1	-1	0	-1	0	0	*0*	*-1*
El-Dakahlia	0	-1	-1	-1	-1	-1	0	*0*	*0*
El-Sharkia	0	-1	-1	0	-1	0	0	*1*	*-1*
El-Ismailia	0	-1	-1	0	-1	1	0	*0*	*0*
Lower (avg)	**-0.14**	**-0.86**	**-0.71**	**-0.29**	**-1**	**-0.14**	**0**	***0.143***	***-0.43***
Beni Suef	-1	0	1	1	1	-1	-1	*-1*	*-1*
El-Fayoum	-1	-1	1	0	1	-1	-1	*-1*	*-1*
El-Menya	-1	0	1	0	1	-1	-1	*-1*	*-1*
Middle (avg)	**-1**	**-0.33**	**1**	**0.33**	**1**	**-1**	**-1**	***-1***	***-1***
Assiut	-1	-1	1	0	1	-1	-1	*-1*	*-1*
Sohag	-1	-1	0	0	1	-1	-1	*-1*	*0*
Qena	-1	0	1	0	1	-1	-1	*-1*	*-1*
Aswan	0	1	1	0	1	-1	0	*-1*	*0*
Luxor	-1	0	0	1	1	0	-1	*-1*	*-1*
Upper (avg)	**-0.8**	**-0.2**	**0.6**	**0.2**	**1**	**-0.8**	**-0.8**	***-1***	***-0.6***
Matruh	-1	0	-1	1	-1	1	-1	*-1*	*0*
North Sinai	-1	0	0	0	-1	1	0	*-1*	*0*
New Valley	0	-1	1	0	0	-1	0	*0*	*1*
Border (avg)	**-0.67**	**-0.33**	**0**	**0.33**	**-0.67**	**0.33**	**-0.33**	***-0.67***	***0.33***
National mean	**-0.53**	**-0.53**	**0**	**0.05**	**-0.11**	**-0.32**	**-0.36**	***-0.305***	***-0.339***

† For the Egyptian governorates: -1 = overutilization; 0 = adequate level; + 1 = underutilization. Regional and national averages are interpreted according to the following scale: LSI < -0.75 strong overutilization; -0.75 ≤ LSI < -0.50 moderate overutilization; -0.50 ≤ LSI < -0.25 weak overutilization; -0.25 ≤ LSI ≤ 0.25 correct use; 0.25 < LSI ≤ 0.50 weak underutilization; 0.50 < LSI ≤ 0.75 moderate underutilization; and 0.75 < LSI strong underutilization.

These results may be explained by supply constraints on various inputs in different regions rather than policy decisions of farmers. Special attention should be given to a more equitable distribution of fertilizers and pesticides which are in correct use or overutilized in the North and underutilized in the South. Overutilization of land and labor in governorates of

Middle and Upper Egypt—and to a lesser extent in Border governorates—reflects the limited opportunities available for work outside agriculture, and hence the tendency to engage more workers—especially family workers in on-farm activities—and to exploit land more intensively. The results for the governorate of New-Valley reflect the scarcity of labor in this governorate.

4.2. Determinants of Economic Efficiencies

To try to explain differences in technical and in allocative efficiency levels across farms and hence villages, governorates and regions, several regressions have been run using various likely determinants of these efficiencies. The choice of explanatory variables was to a great extent dictated by data availabilities. Structural problems, associated with inadequate research, training and extension services, poorly performing factor and product markets, inadequacy of water use and irrigation, among other factors may be reducing the efficiency of agricultural production in all areas of the country. Other determinants of efficiency are access to financing, to markets (for products and intermediate inputs), and to supporting services (marketing, information, infrastructure, network of canals and drains). The quality of inputs, such as seeds (high yielding versus traditional varieties), machinery (lazer) and fertilizers (composite versus traditional), is also an important determinant of efficiency.

However, data availability restricted our choice of explanatory variables to the *size of farm*, *household size* and *farmer's gender*[10] as given in AFIS; the *percentage of family workers to total workers by farm*;[11] the *percentage of non-traditional to traditional crops*[12] (measured by the value of non-traditional to traditional crops per farm entering the DEA). The *education level of farmers proxied by the illiteracy rate per village* obtained from the 2006 Population Census; the *poverty rate* per markaz or village, as obtained from the targeting map based on the 2006 Population Census and the Household Income, Expenditure and Consumption Survey (HIECS) for 2005/06 were also considered. In addition to these variables, regional dummies were used to test for differences in fixed regional effects. Taking Upper Egypt as a benchmark, four dummies were included representing successively

[10] This variable was proxied by a dummy variable equaling 0 for male and 1 for female farmers.

[11] This variable is used to test whether there were efficiency gains associated with the use of family labor.

[12] The use of this variable is meant to test whether the composition of output affects agricultural efficiency.

Metropolitan, Lower and Middle Egypt and Border regions.[13]

Two models have been specified to identify factors influencing technical (TE) and allocative (AE) efficiencies successively. Two sets of regressions have been run for each model, one using ordinary least squares (OLS) and the other using Tobit (Maddala 1983). The Tobit model should be used when there is a nontrivial fraction of zeros in the dependent variable while the remaining values are roughly continuously distributed over positive values. The models have also been run with and without the regional dummies. When regional dummies are introduced, they overshadow the effect of illiteracy rate on *technical efficiency*. They further show that, when using OLS, the constant term in the technical efficiency equation is significantly higher in Metropolitan governorates and lower in Middle Egypt than that for Upper Egypt. Other regional dummies, although diverging in sign and magnitude, are not significant, implying that regional factors in both Lower Egypt and Border governorates do not yield significantly different impacts on technical efficiency from those affecting Upper Egypt as shown in Table 5.

Tobit estimates show that the impact of regional effects on technical efficiency in Metropolitan areas is positive at the 1 percent significance level, confirming our previous finding of higher technical efficiency in metropolitan governorates compared to Upper Egypt. For Middle Egypt governorates, regional factors have a negative impact on technical efficiency at the 1 percent significance level, confirming also our previous observation when analyzing technical efficiency.

Table 5 also displays the results of the estimated relations excluding regional dummies. Both methods of estimation—OLS and Tobit—yield comparable results. Technical efficiency shows a significant constant term equaling 0.363. TE is negatively affected by both the household size and the percentage of family labor to total workers; it is also negatively affected by the poverty rate, as well as by the illiteracy rate. This indicates that TE decreases as poverty rates rise and that the level of education, as expected, has a positive impact on technical efficiency. The farm size affects, positively and at 1 percent significance level, technical efficiency, indicating that larger farms are technically more efficient than small

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[13] Other explanatory variables have also been tried, among which are the main occupation of the head of household and the quality of land at the village level. The first variable was taken at the farm level, from AFIS and the latter was obtained at the village level from MALR. None of these variables showed any significant effect.

farms. This finding supports the necessity of collective exploitation of small landholdings. The percentage of non-traditional to traditional crops has a negative and weakly significant effect (at the 10 percent level) on technical efficiency. Finally, farmer's gender has a positive and significant effect on TE.

Table 5. Determinants of Technical Efficiency

	(1) OLS	(2) Tobit	(3) OLS	(4) Tobit
Const.	0.3355**	0.3355***	0.363**	0.363***
	(0.01526)	(0.01527)	(0.01382)	(0.01388)
Household size	-0.001877**	-0.001877**	-0.002141**	-0.00214***
	(0.0007973)	(0.001)	(0.0008096)	(0.00081)
Farm size	3.976e-05**	3.976e-05**	5.493e-05**	5.6e-05***
	(1.612e-05)	(1.025e-05)	(1.589e-05)	(1.6e-05)
% of family labor	-0.0004263**	-0.000426***	-0.0002741**	-0.000273**
	(0.0001344)	(0.00014)	(0.0001261)	(0.0001267)
% of non-traditional crops	-8.868e-06*	-8.77e-06*	-8.007e-06*	-7.87e-06*
	(4.755e-06)	(4.79e-06)	(4.719e-06)	(4.74e-06)
Poverty rate	-0.0008660**	-0.000866***	-0.0007315**	-0.000734***
	(0.0002461)	(0.0003292)	(0.0001902)	(0.000191)
Illiteracy rate	0.04005	0.04	-0.08512**	-0.08557***
	(0.03416)	(0.03666)	(0.02792)	(0.02805)
Female	0.03142**	0.0319***	0.02911**	0.029586**
	(0.01176)	(0.0118)	(0.01194)	(0.012)
Metropolitan	0.08754**	0.0875***		
	(0.01556)	(0.0156)		
Lower Egypt	-0.008062	-0.008062		
	(0.008696)	(0.008794)		
Middle Egypt	-0.05307**	-0.05306***		
	(0.01019)	(0.01023)		
Border	0.002423	0.00276		
	(0.01097)	(0.011)		
N	2422	2422	2422	2422
Adj-R^2	0.0563		0.0245	
F	14.13		9.7	
	[0.0000]		[0.0000]	
χ^2		150.11		67.08
		[0.0000]		[0.0000]
σ (1)		0.127***		0.129***
		(0.0018)		(0.0019)

Standard errors in parentheses, and p-values in brackets.

* indicates significance at the 10 percent level; ** indicates significance at the 5 percent level; and *** indicates significance at the 1 percent level.

(1) σ is the standard deviation of the normal distribution of the error term. It is reported to help calculate the adjustment factor that is multiplied by the Tobit estimates to obtain the partial effects of the explanatory variables to allow comparison between OLS and Tobit parameter estimates.

With respect to *allocative efficiency*, as shown in Table 6, the introduction of regional dummies shows that for both OLS and Tobit estimates, allocative efficiency is significantly lower in Metropolitan and in Border governorates than it is in Upper Egypt. As to regional differences between Lower and Middle Egypt, on one hand, and Upper Egypt on the other, they were found to be significantly higher in the first two than in the latter.

Table 6. Determinants of Allocative Efficiency

	(1) OLS	(2) Tobit	(3) OLS	(4) Tobit
Const.	0.7445**	0.7443***	0.7596**	0.7595***
	(0.01488)	(0.015)	(0.01446)	(0.01446)
Household size	0.002436**	0.002442***	0.003040**	0.003047***
	(0.0007775)	(0.0007768)	(0.0008473)	(0.000847)
Farm size	-0.0001075**	-0.000107***	-0.0001874**	-0.000187***
	(1.572e-05)	(1.57e-05)	(1.663e-05)	(1.66e-05)
% of family	0.0008358**	0.0008377***	-9.831e-05	-9.8e-05
labor	(0.0001311)	(0.000131)	(0.0001319)	(0.0001319)
% of non-	9.871e-06**	9.91e-06**	-7.951e-06	-7.95e-06
traditional crops	(4.637e-06)	(4.63e-06)	(4.938e-06)	(4.94e-06)
Poverty rate	0.002231**	0.002233***	0.001253**	0.001254***
	(0.0002399)	(0.0002397)	(0.0001991)	(0.000199)
Illiteracy rate	-0.2330**	-0.2332***	0.01024	0.01025
	(0.03331)	(0.03328)	(0.02922)	(0.02922)
Female	0.008282	0.008337	0.009232	0.009285
	(0.01146)	(0.01145)	(0.01250)	(0.0125)
Metropolitan	-0.03903**	-0.03899**		
	(0.01517)	(0.01516)		
Lower Egypt	0.06731**	0.06737***		
	(0.008480)	(0.0084)		
Middle Egypt	0.1000**	0.1001***		
	(0.009939)	(0.0099)		
Border	-0.09827**	-0.09849***		
	(0.01070)	(0.01069)		
N	2422	2422	2422	2422
Adj-R^2	0.223		0.0743	
F	63.98		28.76	
	[0.0000]		[0.0000]	
χ^2		619.76		193.48
		[0.0000]		[0.0000]
σ [(1)]		0.123***		0.134***
		(0.00177)		(0.0019)

Standard errors in parentheses, and p-values in brackets.

* Indicates significance at the 10 percent level; ** indicates significance at the 5 percent level; and *** indicates significance at the 1 percent level.

(1) σ is the standard deviation of the normal distribution of the error term. It is reported to help calculate the adjustment factor that is multiplied by the Tobit estimates to obtain the partial effects of the explanatory variables to allow comparison between OLS and Tobit parameter estimates.

AE is significantly positively affected by the household size, the percentage of family workers in total on-farm labor, the percentage of non-traditional to traditional crops, and the poverty rate. The positive sign associated with the coefficient of the poverty rate supports the view that poorer farmers are more parsimonious and careful about achieving cost efficiency. In contrast, farm size and illiteracy rates are significantly and negatively related to allocative efficiency. The negative signs associated with these two variables suggest successively that farmers with small landholdings may be more concerned about cost efficiency, hence achieving higher rates of AE, and that higher education level (lower illiteracy rate) is likely to enhance AE, which is in conformity with the result obtained for the impact of education on TE. Finally, the variable reflecting farmer's gender did not show any significant effect on AE.

Disregarding regional dummies, allocative efficiency indicates a significant constant term of around 0.760. AE remained significantly and positively affected by the household size and the poverty rate. It also remained significantly and negatively affected by the farm size. However, the percentage of family workers in total on-farm labor, the percentage of non-traditional to traditional crops and the illiteracy rate as well as farmer's gender showed no significant effect.

5. Concluding Remarks

National efficiency indices for Egypt revealed considerable technical inefficiency in crop production in 2003/04, which if avoided, could have led to savings of up to 31.4 percent of inputs used. Furthermore, had all villages produced at the technically efficient frontier, this may have led to up to a 45 percent increase in crop production. Technical efficiency was found to be higher in areas with larger size landholdings and probably relatively less labor-intensive pattern of production. Producers with larger landholdings are usually better connected to processing and marketing firms and have better access to international markets. Technical efficiency was primarily determined by the constant term which reflects soil, climate, irrigation and other natural conditions characterizing various regions. TE was also found to be negatively affected by household size, the percentage of family workers to on-farm labor, the percentage of non-traditional to traditional crops, the poverty rate and illiteracy rate. Conversely, farm size and farmer's gender positively impact TE. Observed increasing returns to scale confirms the necessity of consolidating exploitation of small landholdings to benefit from the advantages of economies of scale.

Regarding allocative efficiency, national average indicated considerable inefficiencies in production. These inefficiencies were observed in all villages, governorates and regions. Governorates with lower allocative inefficiency levels were concentrated in Middle Egypt and in border regions. There is evidence that more education (less illiteracy) is correlated with improved AE. Simulations of cost minimization indicated that land, labor and seeds were overutilized in Middle and Upper Egypt, while animal labor and pesticides were strongly underutilized and fertilizers were weakly underutilized in these regions. Machine and animal inputs were overutilized in Metropolitan areas. This reflects that farmers in Middle and Upper Egypt are more likely to experience shortages in essential factors of production, primarily material inputs, unlike in Lower Egypt and Metropolitan governorates which enjoy ample supply of machines, animal and material inputs. Economic efficiency indices were equally driven by both allocative and technical efficiencies.

Further study is required to test the influence of scientific knowledge investment results and to assess the impact of extension services spending on these indices. Investigation of the impact of various irrigation methods on efficiency of crop production is also warranted.

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