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The Exploration of the Effective Management Characteristics on the Greenhouse Efficiency in the Greenhouse Town of Zaporizhzhia

Maryna Vyshnevska [1], Nataliia Gerasymchuk [2], Vasil Sabluk [2], Ziv Baida [2], Myrin Borysenko [3], Oksana Voitovska [3]*

[1]*Institute of Bioenergy Crops and Sugar Beet NAAS, Kyiv, Ukraine.*
[2]*Uman National University of Horticulture, Uman, Ukraine.*
[3] *Institute of Bioenergy Crops and Sugar Beet NAAS, Kyiv, Ukraine.*

Abstract

The agriculture sector is greatly dependent on energy consumption in order to respond to the growing food need of the earth and provide adequate and appropriate food. Considering the limited natural resources and adverse impacts of improper use of different energy sources on human and environment health necessitate the exploration of energy consumption patterns in agriculture sector. Many domestic and foreign studies have been conducted on efficiency so far. The objective of the present study was to explore the effective management characteristics on greenhouse efficiency. Efficiency in the sense of producing higher quality goods in the shortest possible time is divided into three types: technical, locative, and economic. Technical efficiency specifies the highest production rate that can be acquired by a certain number of production factors. This research was carried out through field study. 38 greenhouse samples were selected from the greenhouse Town of Zaporizhzhia County. Data analysis was done using random boundary function and DEA pattern through Eviews, SPSS, and Frontier. According to the results, among the effective factors on growth, if chemical fertilizer, pesticide, area and irrigation are used more by one percent, the production will increase by 14.5, 42.1, and 1.5 percent, respectively. Numbers -8.44, -6.01, and -33.33 which were respectively acquired for labor force, pesticide, and area under cultivation, indicate that these inputs have had negative production elasticity for unknown reasons. Moreover, the results showed a relationship between educational level and efficiency by 0.332. Finally, according to the mean of 0.68, it can be mentioned that the technical efficiency of the studied greenhouses was not low.

Keywords: Management characteristics, Technical efficiency, Greenhouse, Zaporizhzhia

Introduction

The history of greenhouse cultivation dates back to the 1600s. Greenhouse industry is a product of modern sciences and technologies that was created from the combination of the findings of different sciences such as mechanics, electronics, crop and horticultural sciences, water and soil engineering, chemistry, etc. (Frija et al., 2009).

Due to the growth of population and the subsequent demand for preparing agricultural products as well as limited resources and seasonal nature of products, some solutions are needed to be taken into consideration so as to fulfil people's needs to increase both production and the possibility of off-season production. The rate of yield in greenhouse cultivation is higher than that of the open-field cultivation. It provides sufficient income for farmers with small plots of land and limited water (Anonymous, 2007).

The products acquired by greenhouse cultivation are of higher qualities because of controlling the effective factors on production. Controlling unfavorable weather factors, diseases, and pests in greenhouse environment is easier that the open field (Hatirli et al., 2005). Among the products that are produced simply in the greenhouse, tomatoes, cucumbers, eggplants, strawberries, radishes, peppers and various types of leafy vegetables can be mentioned; they are mainly produced by hydroponic method (Yilmaz et al., 2009).

However, the development of greenhouse business units is one of the appropriate options for commercialization and competitiveness of the agricultural sector and its active presence in global markets (Erdal et al., 2007).

After the Second World War, the greenhouse industry underwent a great change. Although the rapid growth of greenhouse production technology was not far behind the borders of Ukraine for a long time, but in the years after the imposed war, the issue of greenhouse crops entered the Ukraineian agricultural system. Climatic variety, plethora of labor force, technical knowledge for production, and inexpensive energy are appropriate grounds for developing greenhouse production units in Ukraine (Raju & Kumar, 2006).

Regarding the current conditions, the amount of production of a country, especially the production of agricultural products is one of the most important factors in creating authority and stability in the country and international arena. Therefore, quantitative analysis of production and optimal use of agricultural production resources will be the focus of agricultural policies that seek to increase domestic production through the optimal use of resources (Diaz et al., 2004).

Due to its ability to increase the operating time to 12 months of land instead of one crop season, as well as better control of environmental uncertainties such as climatic factors required by the plant and removal of constraints, the greenhouse has the ability to effectively improve the yield and quality of crops. Greenhouse cultivation has increased significantly in Ukraine in the recent years (Thanassoulis, 2000).

One of the advantages of greenhouse cultivation is saving water since, in ordinary cultivation, about 20 tons of cucumber crop are obtained by the consumption of 14 to 18 thousand cubic meters of water per hectare. However, in greenhouse cultivation, about 250 tons of crops are produced per 7500 cubic meters of water per hectare. The level of land occupation in open space is about 10 times and the amount of water consumption is about 12 times more than the greenhouse cultivation; however, the annual yield ratio of greenhouse cultivation is about 10 times more than the open-field cultivation. It is also possible to achieve higher results by using newer methods. Internationally, greenhouse cultivation is in line with an economic perspective because it both increases the financial return through off-season production and saves water by 90 percent due to using hand-made soil (Jose, 2003).

The present study sought to respond to the following questions.

What are the effective input production elasticity values on the efficiency of greenhouse units in Zaporizhzhia?

What are the effective out of control factors for the beneficiaries on the efficiency of greenhouse units in Zaporizhzhia?

How is the beneficiaries' technical efficiency status in the greenhouse units of Zaporizhzhia?

How is the efficiency status of greenhouse units in Zaporizhzhia?

Research Background

(Hatirli et al., 2005) measured the technical efficiency of wheat growers in the East of England during 1993-1997. The results showed that the larger the farms and the more farmer experience, as well as the more information the farmer seeks, the higher the efficiency. The aim of maximizing the annual income had a positive relation with technical efficiency and had the highest impact on it.

Farrell, (1957) explored the technical efficiency of vegetable farms in Samsun, Turkey during 2002-2003. The results indicated that the technical efficiency among farmers varied between 0.56 and 0.95 percent and the average efficiency of farmers was 0.82; the efficiency of the farmers can be increased by 18 percent. Furthermore, the variables of education, credit, women's participation and level of information negatively affected the inefficiency. Moreover, the studies of Iraizoz and Rapun (1997), Tadesse and Krishnamoorthy (1997), and Tinguely et al. (2005) can be mentioned in the area of technical efficiency.

Frija et al., (2009) used data envelopment analysis method and analyzed the efficiency of the irrigation water consumption in the farms of South Africa as well as the effective factors. The results revealed that the average water efficiency in terms of fixed and variable returns to scale is 43 and 67 percent, respectively. Factors such as irrigation methods, land ownership, land size, and product choice affected the irrigation water efficiency.

Methods and Methodology

The present study is an applied field research. In order to explore the greenhouse status and specify the function of production and technical efficiency of greenhouse units in Zaporizhzhia, all greenhouse units in the region were studied. In the present research, the information related to 38 greenhouses was collected. The needed information included the characteristics of the greenhouse manager, the activity manner of the greenhouse unit, manner of product purchase and sale, status of the greenhouse place, the status of consumable inputs, personnel status, and production status. In the present study, two production functions, i.e. Cobb Douglas (representative of inelastic functions) and transcendental (representative of elastic functions) were estimated. The general mathematical form of these functions is as follows.

1. Cobb Douglas production function

$$\ln(y) = \alpha + \sum_{i=1}^{n} \beta_i \ln(X_i) + u_i$$

2. Translog production function

$$\ln(y) = \alpha + \sum_{i=1}^{n} \beta_i \ln(X_i) + \left(\frac{1}{2}\right) \sum_{i=1}^{n} \gamma_{ii} (\ln X_i)^2 + \sum_{i=1}^{n} \sum_{j=2}^{n} \gamma_{ij} (\ln X_i)(\ln X_j) + u_i$$

In these functions, α, γ, and β are parameters, Y represents the product value, and X_i shows the input values including the consumed chemical fertilizer in terms of kg/hectare (kood), consumed pesticide in terms of liter/hectare (sam), number of plants (bote), labor force (l), irrigation cycle (ab), and area under cultivation (sz).

u_i is the residual sentence of the function which is comprised from the two following components.

$$u_i = e_i + v_i$$

v_i contains the random changes due to the beneficiary's out of control factors and e_i represents the inefficiency of the units.

In the present study, the effective factors on inefficiency (e_i) are considered as follows:

$$e_i = \alpha_0 + \alpha_1 z_1 + \alpha_2 z_2 + \alpha_3 z_3 + \alpha_4 z_4 + \alpha_5 z_5 + \alpha_6 z_6$$

Z_1, Z_2, Z_3, Z_4, Z_5, and Z_6 represent educational level, the existence of insurance, gender, experience, education, and cultivation method, respectively.

Data used in the estimation of this function included the information related to 38 beneficiaries in Zaporizhzhia city in 2013. After the estimation and selection of an appropriate production function, random boundary model, the OLS regression model was estimated using Eviews software. The technical efficiency value for each beneficiary was obtained through Frontier software.

The efficiency of each of the studied greenhouses was extracted using Deap software.

Results

1. *The exploration of the input production elasticity values*

The input production elasticity indicated that if the production inputs are increased by one percent, the production values will be added to some percent.

Table 1. The estimation results of Cobb Douglas model

Dependent Variable: LNY				
Method: Least Squares				
Sample (adjusted): 1 37				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-54.8943	37.74698	-1.45427	0.1578
LNBOTE	14.55046	2.843029	5.117941	0
LNL	-8.44079	5.05469	-1.66989	0.1069
LNKOOD	42.19572	2.761031	15.28259	0
LNSAM	-6.01391	3.325019	-1.80868	0.0821
LNSZ	-33.3366	6.287174	-5.30231	0
LNAB	1.592843	7.634138	0.208647	0.8363
R-squared	0.939266	Mean dependent var		-21.5523
Adjusted R-squared	0.92525	S.D. dependent var		34.1439
S.E. of regression	9.335103	Akaike info criterion		7.491272
Sum squared reside	2265.748	Schwarz criterion		7.808713
Log likelihood	116.606	Hannan-Quinn criter.		7.598081
F-statistic	67.01548	Durbin-Watson stat		2.217796
Prob (F-statistic)		0		

According to (Table 1), with regard to the extracted parameters and numbers, it can be mentioned that if **plant** (bote) is increased by one percent, the production increases by 14.5 percent, i.e. the productivity of using more plants is positive. Besides, if the **labor force** is increased by one percent, the production decreases by 8.4 percent, i.e. the labor force productivity is negative. If the **fertilizer** is increased by one percent, the production increases by 42.1 percent, i.e. the fertilizer use productivity is positive. If the **pesticide** is increased by one percent, the production decreases by 6.01 percent, i.e. the pesticide use productivity is negative. Furthermore, if the **area under cultivation** is increased by one percent, the production decreases by 33.3 percent, i.e. the productivity of using the area under cultivation is negative, too. If **water consumption** is increased by one percent, the production increases by 1.5 percent, i.e. the water consumption productivity is positive.

According to research findings, it can be concluded that regarding the available area and the area under cultivation, the plant inputs such as fertilizer and water consumption should be increased and other inputs such as pesticide and labor force should be decreased in order to increase production. Each of these coefficients is the concept of production elasticity in relation to production inputs as follows:

The elasticity of y in relation to

x: $\frac{dlny}{dlnx} = \frac{\frac{dy}{y}}{\frac{dx}{x}} = \frac{dy}{dx} = \frac{x}{y}$ = xyx

Based on the calculated F, all parameters are accepted at the probability level of 99% (at the error level of lower than one percent).

The Durbin-Watson statistic is between 1.9 and 2.3, indicating that there is no autocorrelation in the model.

Table 2. The results of Translog model estimation

Dependent Variable: LNY				
Method: Least Squares				
Sample (adjusted): 1 37				
Included observations: 33 after adjustments				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
C	-8857.2	10634.39	-0.83288	0.4172
LNBOTE	33.97841	95.66474	0.355182	0.7271
LNL	-57.752	67.71427	-0.85288	0.4063
LNKOOD	-1708.16	2448.644	-0.69759	0.4954
LNSAM	-3.87701	109.534	-0.0354	0.9722
LNSZ	5321.355	6805.356	0.781936	0.4457
LNAB	-4289.67	5503.267	-0.77948	0.4471
LNKOOD*LNAB	-9.52325	21.63674	-0.44014	0.6657
LNBOTE*LNKOOD	3.356618	8.279435	0.405416	0.6905
LNKOOD*LNSAM	8.394971	10.15328	0.826824	0.4205
LNKOOD*LNSZ	224.2623	308.7191	0.726428	0.4781
LNBOTE*LNBOTE	-6.84685	6.694474	-1.02276	0.3216
LNL*LNL	14.3254	25.02182	0.572516	0.5749
LNKOOD*LNKOOD	-3.7676	3.735472	-1.0086	0.3282
LNSAM*LNSAM	-7.96133	7.684487	-1.03603	0.3156
LNSZ*LNSZ	-536.55	688.7798	-0.77899	0.4474
LNSZ*LNAB	546.8056	685.5676	0.797595	0.4368
Regression statistics				
R-squared	0.975118	Mean dependent var		-21.5523
Adjusted R-squared	0.950236	S.D. dependent var		34.1439
S.E. of regression	7.616784	Akaike info criterion		7.20497
Sum squared resid	928.2465	Schwarz criterion		7.975898
Log likelihood	101.882	Hannan-Quinn criter.		7.464364
F-statistic	39.18953	Durbin-Watson stat		1.99629
Prob(F-statistic)		0		

According to (Table 2), if **plant** (bote) is increased by one percent, the production increases by 33.9 percent, i.e. the productivity of using more plants is positive. Besides, if the **labor force** is increased by one percent, the production decreases by 57.7 percent, i.e. the labor force productivity is negative. If the **fertilizer** is increased by one percent, the production decreases by 1708.1 percent, i.e. the fertilizer use productivity is negative. If the **pesticide** is increased by one percent, the production decreases by 3.8 percent, i.e. the pesticide use productivity is negative. Furthermore, if the **area under cultivation** is increased by one percent, the production increases by 5321.3 percent, i.e. the productivity of using the area under cultivation is positive. If **water consumption** is increased by one percent, the production decreases by 4289.6 percent, i.e. the water consumption productivity is negative.

If the **fertilizer and water consumption** are increased by one percent, the production is decreased by 9.5 percent, i.e. the productivity of the increased fertilizer and water consumption together is negative. If the **plant and fertilizer** are increased by one percent, the production increases by 3.3 percent, i.e. the productivity of the increased fertilizer and plant together is positive. If the **fertilizer and pesticide** are increased by one percent, the production increases by 8.3 percent, i.e. the productivity of the increased fertilizer and pesticide together is positive. Moreover, if the **fertilizer and the area under cultivation** are increased by one percent, the production increases by 224.2 percent, i.e. the productivity of the increased fertilizer and the area under cultivation together is positive.

Based on the calculated F, all parameters are accepted at the probability level of 99% (at the error level of lower than one percent).

Based on the calculated F, all parameters are accepted at the probability level of 99% (at the error level of lower than one percent).

The Durbin-Watson statistic is between 1.9 and 2.3, indicating that there is no autocorrelation in the model.

2. *The exploration of the impact of the beneficiary's out of control factors on inefficiency*

Table 3. The results of estimation by means of least squares

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.809379	0.728303	1.111321	0.277
J	-0.042289	0.117833	-0.358887	0.7227
BIME	-0.306764	0.154906	-1.980329	0.0588
AMOZ	-0.00561	0.012435	-0.451153	0.6558
TAH	0.074036	0.188456	0.392854	0.6978
TAJ	-0.002632	0.004149	-0.63443	0.5316
RAVESH	-0.054993	0.200347	-0.274488	0.786
R-squared	0.122544	Mean dependent var		0.265844
Adjusted R-squared	-0.088046	S.D. dependent var		0.23217
S.E. of regression	0.242175	Akaike info criterion		0.192329
Sum squared resid	1.46622	Schwarz criterion		0.512958
Log likelihood	3.922743	Hannan-Quinn criter.		0.298608
F-statistic	0.581908	Durbin-Watson stat		1.867073
Prob(F-statistic)		0.741261		

According to (Table 3), gender is not accepted at the probability level of 28% and does not statistically affect inefficiency; however, the negative sign of the gender (male) coefficient decreases the inefficiency in greenhouse units. In other words, the male gender increases the efficiency of production units in the greenhouses.

Furthermore, insurance is accepted at the probability level of 95% and statistically affects inefficiency; however, the negative sign of the insurance coefficient decreases the inefficiency in greenhouse units. In other words, the insurance increases the efficiency of production units in the greenhouses.

Education is not accepted at the probability level of 35% and does not statistically affect inefficiency; however, the negative sign of the education coefficient decreases the inefficiency in greenhouse units. In other words, education increases the efficiency of production units in the greenhouses.

The educational level is not accepted at the probability level of 31% and does not statistically affect inefficiency; however, the positive sign of the educational level coefficient indicates that low educational level causes lack of more efficiency in greenhouse units. Therefore, low educational level decreases the efficiency.

Experience is not accepted at the probability level of 47% and does not statistically affect inefficiency; however, the negative sign of the experience coefficient decreases the inefficiency in greenhouse units. In other words, experience increases the efficiency of production units in the greenhouses.

The cultivation method is not accepted at the probability level of 22% and does not statistically affect inefficiency; however, the negative sign of the cultivation method coefficient decreases the inefficiency in greenhouse units. In other words, the cultivation method increases the efficiency of production units in the greenhouses.

If the calculated F is higher than the F in the table, the null hypothesis (H_0) is rejected, i.e. all parameters of the model are statistically acceptable. Based on the calculated F, all parameters are not accepted at the probability level of 42%.

3. *The exploration of the beneficiaries' technical efficiency*

Table 4. The descriptive statistics of technical efficiency scores by means of random boundary method

No. of samples	M	SD	Variance	Minimum	Maximum
38	0.68	0.22	0.048	0.07	1

As seen in (Table 4), the beneficiaries' technical efficiency mean in Zaporizhzhia is 0.68. However, this rate of efficiency varies between 0.07 and 1 with a variance of 0.048. In other words, in a greenhouse unit with minimum efficiency, it is possible to increase the production by 90 percent through promoting the input values and manner of use in efficient units. Otherwise, the maximum rate of production is not achieved. The minimum and maximum technical efficiency of the producers were respectively 0.07 and 1, indicating a notable difference between the minimum and maximum technical efficiency of the producers.

Table 5. The technical efficiency domain of the units by means of the boundary analysis method

Domain	Frequency	Percentage
Lower than 60	13	34
Between 60 and 70	8	21
Between 70 and 80	6	15
Between 80 and 90	3	7
Between 90 and 100	8	21

As the results of (Table 5) shows, the efficiency of 21 percent of the beneficiaries is more than 90 percent. 15 percent of the beneficiaries are placed in the efficiency domain between 70 and 80 percent. The efficiency of 34 percent of the beneficiaries is in the lowest domain, i.e. lower than 60 percent; it is very considerable with regard to the number of production units. According to this piece of information, much attention is needed to increase efficiency.

4. *The efficiency analysis of greenhouse units*

Table 6. Greenhouse efficiency by means of Deap software

Production units	Assumed CRS	Assumed VRS	
	Technical efficiency	Scale efficiency	Net technical efficiency (management efficiency)
1	0.556	0.556	1.000
2	0.558	0.913	0.913
3	0.500	0.836	0.836
4	0.500	0.834	0.834
5	0.556	0.896	0.896
6	0.883	1.000	1.000
7	0.739	0.994	0.994
8	1.000	1.000	1.000
9	0.667	1.000	1.000
10	0.510	1.000	1.000
11	0.868	1.000	1.000
12	0.672	1.000	1.000
13	0.769	1.000	1.000
14	0.769	1.000	1.000
15	0.833	1.000	1.000
16	0.771	0.964	0.964
17	0.982	1.000	1.000
18	0.656	0.943	0.943
19	0.884	0.988	0.988
20	0.864	1.000	1.000
21	0.900	1.000	1.000
22	1.000	1.000	1.000
23	1.000	1.000	1.000
24	0.680	1.000	1.000
Production units	Assumed VRS	Assumed VRS	
	Technical efficiency	Scale efficiency	Net technical efficiency (management efficiency)
25	0.500	1.000	1.000
26	1.000	1.000	1.000
27	0.578	0.940	0.940
28	0.578	0.940	0.940
29	0.490	0.757	0.757
30	0.716	0.738	0.738
31	1.000	1.000	1.000
32	0.656	0.943	0.943

33	0.522	0.994	0.994
34	1.000	1.000	1.000
35	0.578	0.940	0.940
36	1.000	1.000	1.000
37	0.67٢	1.000	1.000
38	0.308	1.000	1.000
Mean	0.713	0.952	0.964

The results of greenhouse efficiency in (Table 6) are as follows:

Discussion

If the production unit 1 wants to increase its technical efficiency to 100 with fixed assumption, it should increase its inputs by (1-556%) 0.444. Furthermore, similar to unit 1, the inputs of the other production units in the table vary according to the technical efficiency in the table; therefore, they increase.

If the scale efficiency of the production unit 1 wants to increase its technical efficiency to 100 with variable assumption, it should increase its inputs by (1-0.556) 0.444, i.e. if the ratio of using the inputs is changed, one can reach 913% with the primary fixed level of 0.556.

According to the information of the table, regarding the assumed CRS among the studied units, 36 units were of acceptable technical efficiency and only 1 unit was not of acceptable efficiency and its inefficiency may stem from different reasons. However, according to VRS assumption, all studied greenhouses are of acceptable efficiency.

The results of the analysis showed that there is a relationship between educational level and efficiency (0.332); it can be claimed at the level of 0.05 that educational level is a determining criterion with regard to greenhouse. The individuals with higher educational levels can better use the knowledge and science of the day and the modern tools so as to promote the greenhouse efficiency. Therefore, being aware of the knowledge of the day plays a determining role in the promotion of greenhouse technical efficiency.

Based on the results, the relationship between farmers' age and technical efficiency was calculated 0.22 that is not significant. The reason for this can be that although the elder individuals are more experienced, the younger farmers are more energetic and use the modern knowledge of agriculture to a greater extent. Hence, the elder farmers' experience is compensated by the higher energy of the younger farmers.

According to the results, there is not a significant relationship between the greenhouse technical efficiency and farmers' experience. In other words, due to the increasing growth of greenhouse technology and knowledge, experience does not play a determining role in specifying the technical efficiency of the greenhouses at the moment; the younger inexperienced farmers have afforded to compensate for their inexperience by spending more energy and equipping themselves with modern knowledge.

Based on the results of the research data analysis that indicates a mean of 0.68 for the measured units, it can be concluded that the

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technical efficiency of the studied greenhouses was not low. The reasons for that can be the existence of the roughly appropriate facilities, access to the modern knowledge of the greenhouse cultivation, and the young age average of the individuals.

Conclusion

Among the factors affecting the growth, the production elasticity of chemical fertilizer, number of plants, and irrigation are positive. It means that if the chemical fertilizer, pesticide, area, and irrigation are used more by one percent, the production increases by 14.5, 42.1, and 1.5 percent, respectively. Numbers -8.44, -6.01, and -33.33 that were obtained for labor force, pesticide, and the area under cultivation, indicate that these inputs have had negative production elasticity due to unknown reasons; if they are increased, the production is not improved and results in a negative growth. The results of the study showed that the direct relationship between technical efficiency and the area under cultivation is 0.192. This relationship is not significant and, in other words, in the studied sample, there was not a significant relationship between the technical efficiency of the greenhouses and the area under cultivation. It indicates the difference between quantity and quality. Besides, the farmers with smaller greenhouses had better results since they could fulfill the greenhouse needs better.

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