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Evaluating The Economic Impact of Agricultural Technology Adoption on Wheat Yield Improvement

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ABSTRACT

Agricultural development is a vital issue in the developing world, where the need for faster agricultural growth has become increasingly urgent. In Egypt, where the agricultural sector employs about 20.3% of the workforce and contributes approximately 11% of the Gross Domestic Product (FAOSTAT, 2020), improving wheat productivity is essential. However, domestic wheat production has only met 51% of annual demand between 2000 and 2021.

Improvements in agricultural production in Egypt require the adoption of dynamic practices that include intensifying agriculture and reducing food waste. Despite progress, information regarding the costs and benefits of new technologies remains insufficient, creating uncertainty among farmers. The study aims to analyze the adoption of agricultural technologies and their effects on smallholder farmers in Egypt.

Data for the study was collected in two phases (2020/2021 and 2022/2023) from a sample of 1,266 farming households across ten governorates in Egypt. The results showed that the average age of farmers was 54 years, with males comprising 95% and females 5%. Farmers had an average of 25 years of agricultural experience and obtained agricultural information from various sources, such as extension services, farmer schools, and mobile phones. Although 99% of farmers were part of cooperative societies, 35% of them did not participate in these cooperatives.

The study utilized the endogenous switching regression (ESR) model to estimate the economic impacts of improved wheat varieties. The findings indicated that adopting these varieties increases production by 359 kg and supports farmers' income by 1,770 Egyptian pounds per feddan compared to non-adoption. Additionally, it was found that adoption increases individual wheat consumption by 23%, equivalent to an increase of approximately 21 kg. The study recommends that the government encourage the adoption of improved varieties and facilitate their accessibility to farmers across all governorates.

KEYWORDS: improve varieties - Endogenous switching regression – treatment and heterogeneity.

1. INTRODUCTION

Agriculture is one of the fundamental pillars of the global economy, playing a pivotal role in providing food security and promoting economic development. Given that Egypt is an agricultural country, agricultural activities provide a direct or indirect source of income for 53% of the population. Also it is considered one of the important sectors that absorb the labor force, as the Egyptian agriculture sector employs approximately 20.3% of the labor force and contributes about 15% of the national income (FAOSTAT, 2020). It also contributes to providing the necessary foreign exchange for the development process through agricultural exports, which represent about 17.83% of national exports (shehata, et all, 2022).

In this context, the adoption of agricultural technology has become vital for improving crop productivity, particularly wheat, which is considered one of the most strategic crops in many countries, especially Egypt. It plays a crucial role in the Egyptian diet and is the primary staple food for the country's growing population. However, local wheat production does not meet domestic consumption needs, making it a national priority to increase local production in order to bridge the gap between consumption and production and enhance food security. This goal can be achieved by raising productivity through the adoption of the recommended technology packages in the study, which include improved agricultural techniques and the cultivation of high-yielding varieties.

This study was conducted as part of the " Innovative Agriculture for Small-Holder Resilience (iNASHR) " a collaborative effort between the Agricultural Research Center of Egypt (ARC) and the International Center for Agricultural Research in the Dry Areas (ICARDA). The project developed and disseminated several technology packages aimed at sustainably increasing agricultural production and enhancing food security. It adopts a systematic approach to addressing the sustainable intensification of wheat-based farming systems by promoting a combination of integrated cropping system technologies to tackle a broad range of challenges in a more sustainable way. The study governorates were selected based on their relative importance in terms of average wheat cultivated area and the number of farmers. Therefore, the application of these technology packages in these governorates holds significant potential for boosting wheat production in Egypt.

Research shows that the main goal of enhancing productivity has not been fully realized due to the slow or, at times, lack of adoption of Green Revolution technologies. Although there is evidence indicating that these technologies have significantly transformed agriculture in regions like Europe and Southeast Asia (Damba et al., 2020), many studies over the years have focused on innovation and the adoption of new technologies in developing countries. Additionally, the process of adoption and the effects of new technology on smallholder farmers have been examined. Despite this, the adoption of modern agricultural technologies often occurs at a slow pace, with many aspects still not well understood, even though they are seen as a crucial pathway out of poverty in most developing countries. Agricultural improvements can be achieved through the adoption of modern farming techniques, a fact recognized by both governmental and non-governmental organizations as a means to enhance agricultural productivity (Khan et al., 2019).

In this research, we will evaluate the economic impact of adopting agricultural technologies on improving wheat yield, focusing on the factors and challenges influencing farmers' decisions in adopting these technologies. Our aim is to provide comprehensive insights into how agricultural technology can contribute to enhancing food security and fostering sustainable economic development.

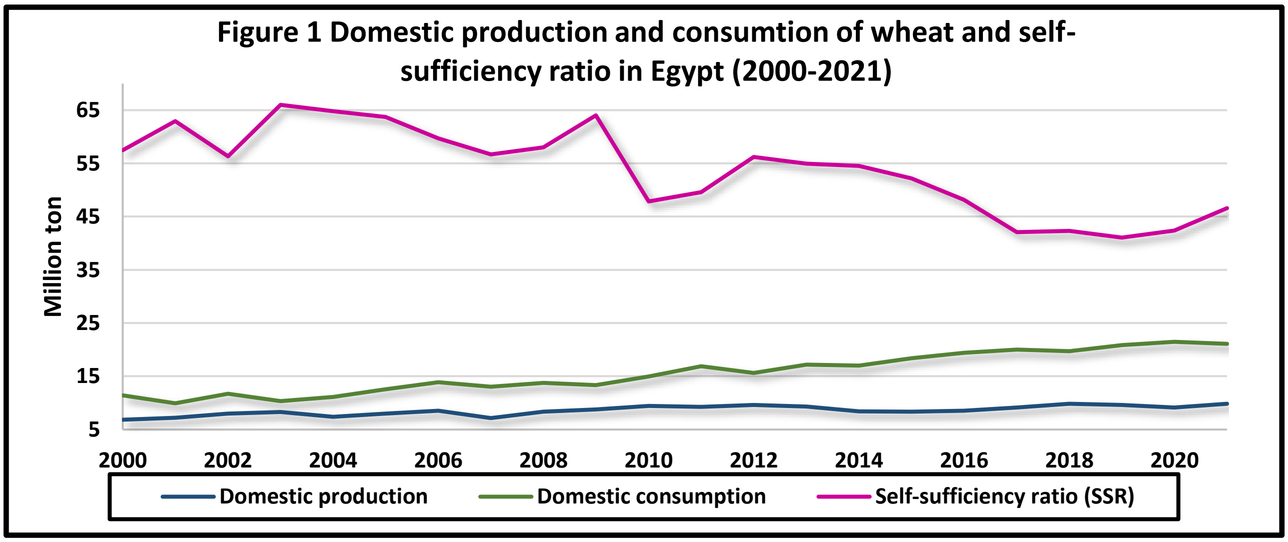
2. RESEARCH PROBLEM

Wheat is the main staple food and the most significant grain crop in Egypt. It serves as the core ingredient for bread, a vital food item consumed in large quantities, which is heavily subsidized and plays a central role in Egypt's politically sensitive food subsidy policy. Wheat is cultivated across Egypt, both within and beyond the Nile Valley, primarily as a winter crop, covering nearly half of the winter crop area. Since

2002, the area under wheat cultivation has almost doubled, increasing gradually from around 2.5 million feddan in 2000 to approximately 3.4 million feddan in 2022 (MALR, 2024).

Egypt sources its wheat from two main channels: domestic production and imports. Domestic wheat production saw a 46% rise, growing from around 6.58 million tons in 2000 to about 9.62 million tons in 2022. At the same time, domestic wheat consumption surged from approximately 11.44 million tons in 2000 to around 21.11 million tons in 2021. This growth in demand was driven by a population increase of about 2.5% annually ("CAPMAS," 2022) and the presence of around 5 million refugees from countries such as Iraq, Syria, Libya, Yemen, and Sudan (Abdi A. et al., 2018).

As a result, wheat imports have also grown, rising from around 4.9 million tons in 2000 to roughly 9.6 million tons in 2022, as depicted in Figure 1. Between 2000 and 2021, Egypt achieved only 51% self-sufficiency in wheat, with the remaining 49% covered by imports. To meet its development goals and achieve wheat self-sufficiency, Egypt requires more dynamic and inclusive agricultural practices. Given the country's limited capacity for expanding arable land, this can be achieved through vertical agricultural expansion, which includes intensifying farming practices, adopting modern agricultural techniques, utilizing improved crop varieties, and applying advanced irrigation systems.



Source: Ministry of Agriculture and Land Reclamation (MALR) and Central Agency for Public Mobilization and Statistics (CAPMAS).

Therefore, identifying this problem helps to understand the existing gaps in the adoption of agricultural technology and enhances the ability to improve policies and interventions to support farmers and increase wheat productivity.

3. RESEARCH OBJECTIVES

3.1. Analyze the Characteristics of Household Heads in the Study Area:

Examine the demographic, social, and economic attributes of household heads in the area, including age, educational level, marital status, and occupation, to understand their impact on agricultural decisions.

3.2. Assess Land Ownership among Farmers:

Explore the extent of land ownership among farmers measured in feddan in the study area and analyze its effect on their productivity and technology adoption decisions.

3.3. Investigate the Impact of Dissemination Strategies:

Evaluate the effects of agricultural technology dissemination strategies on the adoption of modern farming practices by farmers and the impact of these strategies on productivity and profitability.

3.4. Comparative analysis of the economic performance of adopting and non-adopting farmers on their profitability.

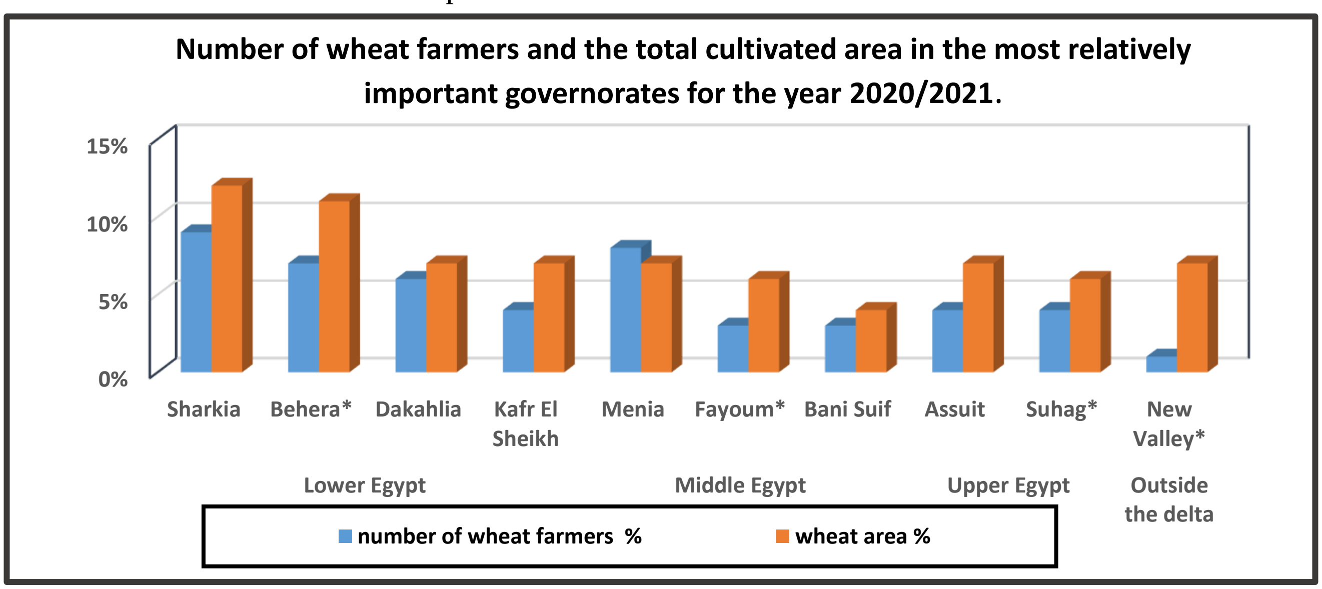
4. DATA

After collecting the essential data and information for the study, a questionnaire was developed to gather all the required details from the farmers. ICARDA collaborated with several enumerators from the statistical center in the governorates involved in the study. These enumerators, who had significant experience in data collection and working with farmers, provided support during the process. After field-testing the questionnaire through personal interviews with selected farmers, necessary adjustments were made to improve its clarity and ease of use, ensuring it was effective in collecting the required information.

The data collection occurred in two phases. The first phase took place in 2020/2021, while the second phase was conducted in 2022/2023. Governorates were selected based on their relative importance in terms of wheat cultivation area and the number of wheat farmers across the Arab Republic of Egypt for the year 2020. Sharkia Governorate was the largest in Lower Egypt, representing about 12% of the wheat area and 9% of the wheat farmers in the Republic. It was followed by Dakahlia and Kafr El Sheikh, each accounting for around 7% of the wheat area and approximately 6% and 4% of the wheat farms in the Republic, respectively. Behera Governorate, compared to other Lower Egypt governorates, represented about 11% of the wheat area and around 7% of the Republic's wheat farmers.

As illustrated in Figure (2), Menia and Beni Suef were the two leading governorates in Middle Egypt in terms of wheat-cultivated area, representing approximately 7% and 4% of the Republic's total, respectively. The number of farmers in these governorates accounted for 8% and 3% of the total wheat farmers in the Republic. Fayoum, selected as a counterfactual governorate, represented around 6% of the wheat-cultivated area and 4% of the wheat farmers in the Republic.

In Upper Egypt, Assiut had the largest cultivated area of wheat, accounting for about 7% of the Republic's total, with around 4% of the nation's wheat farmers. Suhag served as a counterfactual governorate, representing approximately 6% of the wheat area and 4% of the Republic's wheat farmers. Additionally, the New Valley Governorate, the largest wheat-producing area outside the Nile Valley, contributed around 7% of the total wheat area cultivated nationwide during the study year. This governorate was selected to assess the impact of the technology used and the extent of farmers' adoption.



Source: Ministry of Agriculture and Land Reclamation and Agricultural sector cooperatives in the governorates.
*Counterfactual's governorates.

The minimum sample size was determined using the stratified sampling method, systematically selecting the region and the equivalent proportion of farmers to be included in the sample, while ensuring fair representation of each stratum in the sample. About 1,266 sample households from the top-10 wheat growing governorates were interviewed divided into 743 farmers in certain governorates and 523 farmers in the comparison governorates, selected randomly.

5. METHODOLOGY

Endogenous switching regression (ESR) is a statistical technique commonly used to address issues of selection bias resulting from self-selection in observational or quasi-experimental studies. The strength of this method lies in its ability to tackle biases arising from both observable and unobservable factors.

When using methods such as propensity score matching (PSM), the focus is on reducing bias that arises only from observable factors—those characteristics that can be measured and observed, such as age, education, farm size, etc. However, PSM cannot address factors that are unobservable, such as personal skills or motivation, which can influence study outcomes. For example, in studies related to the adoption of new agricultural techniques, some farmers may have unobserved motivations or abilities that make them more willing to adopt these techniques compared to others, thereby affecting the results.

In contrast, the endogenous switching regression (ESR) method relies on a regression model that estimates the relationship between independent and dependent variables while accounting for differences among individuals or units that decide to participate in the program or intervention. The sample is divided into two groups: participants and non-participants, and separate models are estimated for each group, adjusting for differences resulting from self-selection.

- **Benefits of ESR:**

1. Addressing Unobservable Biases: ESR takes into account unobservable factors that may affect both the participation decision and the outcomes, something that methods like PSM cannot do.

2. Improving Causal Estimates: By addressing endogeneity in the participation decision, ESR allows for a more accurate estimation of the causal relationship between the program (such as agricultural innovations) and outcomes (such as increased productivity or income).

3. Suitability for Studies Using Observational Data: When conducting randomized controlled trials is difficult or impossible, ESR can serve as a robust alternative for analyzing the impact of interventions using non-experimental data.

The difference in important outcomes between adopters and non-adopters may not only stem from observable heterogeneity but may also be the result of unobservable heterogeneity (WuID. 2022). Therefore, we use endogenous switching regression (ESR) to account for both observable and unobservable factors in the adoption decision by simultaneously estimating the adoption function (equation 1) and the outcome equation of interest for each group.

Theoretically, farmers decide to adopt a technology when the expected utility received from adoption (D_1^*)is greater than the utility received from non-adoption (D_0^*). While utility is not observable, adoption is observable and is treated as a dichotomous choice: D =1 if $D_1^* > D_0^*$ and D = 0 if $D_1^* < D_0^*$. Thus, following WuID. 2022, Bidzakin et al. (2019), Adela et al. (2018) and Shiferaw et al. (2014) the ESR can be formulated as follows with the adoption decision (selection equation) modelled as:

$D_i^* = Z_i\beta + \varepsilon_i$ with $D_i = 1 \; if D_i^* > D_0^*$, otherwise $D_i = 0$ (1)

where Z represents a matrix of the explanatory variables, ß is a vector of parameters to be estimated and ε a vector representing normally distributed error term with mean zero and variance σ_ε^2.

The outcome equations can also be formulated as:

$y_1 = X_1\omega_1 + \epsilon_1 \; if \; D = 1$ (2)

$$y_0 = X_0\omega_0 + \epsilon_0 \; if \; D = 0 \tag{3}$$

Where y_i is a vector of dependent variables representing outcomes for adopters (y_1) and non-adopters (y_0), X_i is a matrix of explanatory variables, ω_i is a vector of parameters to be estimated, and ϵ_1, and ϵ_0 are error terms.

The error terms from the three equations ε, ϵ_1, and ϵ_0 are assumed to have a trivariate normal distribution with mean vector zero and the following covariance matrix:

$$cov(\varepsilon, \epsilon_1, \epsilon_0) = \begin{bmatrix} \sigma^2_{\epsilon 0} & \sigma_{\epsilon 1 \epsilon 0} & \sigma_{\epsilon 0 \varepsilon} \\ \sigma_{\epsilon 1 \epsilon 0} & \sigma^2_{\epsilon 1} & \sigma_{\epsilon 1 \varepsilon} \\ \sigma_{\epsilon 0 \varepsilon} & \sigma_{\epsilon 1 \varepsilon} & \sigma^2_{\varepsilon} \end{bmatrix} \tag{4}$$

where σ^2_{ε} is the variance of the selection equation (equation 1), $\sigma^2_{\epsilon 0}$ and $\sigma^2_{\epsilon 1}$are the variances of the outcome equations for non-adopters and adopters while $\sigma_{\epsilon 0 \varepsilon}$ and $\sigma_{\epsilon 1 \varepsilon}$ represent the covariance between ε, ϵ_1, and ϵ_0. If ε is correlated with ϵ_1, and ϵ_0, the expected values of ϵ_1, and ϵ_0 conditional on the sample selection are non-zero:

$$E(\epsilon_1 | D = 1) = \sigma_{\epsilon 1 \varepsilon} \frac{\phi(Z_i\omega_i)}{\Phi(Z_i\omega_i)} = \sigma_{\epsilon 1 \varepsilon}\lambda_1 \tag{5}$$

$$E(\epsilon_0 | D = 0) = \sigma_{\epsilon 0 \varepsilon} \frac{-\phi(Z_i\omega_i)}{1-\Phi(Z_i\omega_i)} = \sigma_{\epsilon 0 \varepsilon}\lambda_0 \tag{6}$$

Where ϕ and Φ are the probability density and the cumulative distribution function of the standard normal distribution, respectively. If $\sigma_{\epsilon 1 \varepsilon}$ and $\sigma_{\epsilon 0 \varepsilon}$ are statistically significant, this would indicate that the decision to adopt and the outcome variable of interest are correlated suggesting evidence of sample selection bias. Therefore, estimating the outcome equations using ordinary least square (OLS) would lead to biased and inconsistent results (Adjin et al. 2020) and Heckman procedures (Heckman, 1979) are normally used. In the face of heteroscedastic error terms, the full information maximum likelihood (FILM) estimator can be used to fit an endogenous switching regression that simultaneously estimates the selection and outcome equations to yield consistent estimates (Adela et al. (2018)). The ESR can be estimated where the actual expected outcomes of adopters (7) and non-adopters (8), and the counterfactual hypothetical cases that the non-adopters did adopt (9) and the adopters did not adopt (10) can be analysed as follows:

$$E(y_1 | D = 1) = X_1\omega_1 + \sigma_{\epsilon 1 \varepsilon}\lambda_1 \tag{7}$$

$$E(y_0 | D = 0) = X_0\omega_0 + \sigma_{\epsilon 0 \varepsilon}\lambda_0 \tag{8}$$

$$E(y_0 | D = 1) = X_1\omega_0 + \sigma_{\epsilon 0 \varepsilon}\lambda_1 \tag{9}$$

$$E(y_1 | D = 0) = X_0\omega_1 + \sigma_{\epsilon 1 \varepsilon}\lambda_0. \tag{10}$$

Finally, we calculate the average treatment effect on the treated (ATT) as the difference between (7) and (10) and the average treatment effect on the non-adopters (ATU) as the difference between (9) and (8) (Adela et al. (2018), Di Falco et al., 2011; Lokshin and Sajaia, 2011; Lokshin and Glinskaya, 2009; Miranda and Rabe-Hesketh, 2006; Carter and Milon, 2005). We also compute the effect of base heterogeneity for the group of adopters (BH_1) as the difference between (7) and (9), and for the group of non-adopters (BH_2) as the difference between (10) and (8).

A number of factors such as varieties used and the amounts of fertilizers, seed, labor, quantity of herbicide and quantity of pesticide are important in determining yield, which in turn will affect income and consumption.

6. RESULTS AND DISCUSSION

6.1 The Characteristics of Household in the Study Area:

The information presented in Table 1 indicates that the average age of household heads is 54 years, with ages ranging from a minimum of 20 to a maximum of 86. The sample predominantly comprises male household heads, who represent 95% of the total, while females account for just 5%.

Table 1 .The characteristics of the Household in the study area.

Characteristics	Mean	Min	Max	SD
Age of household (Years)	54.08	20	86	10.14
Sex of household (1=male, 0=female)	0.95	0	1	0.23
Number of years of education of household	8.78	0	25	5.10
Number of years of farming experience of household	28.88	5	70	12.93

Source: Field Survey Results.

There is considerable variability in the educational attainment of household heads, with some individuals being university graduates who have completed up to 25 years of education, while others are completely illiterate, having no formal education. On average, household heads have around 9 years of education. This suggests that a significant portion of respondents might struggle with understanding complex terminology, which could hinder their ability to adopt certain technological practices.

Additionally, the average farming experience among household heads is approximately 29 years, with experience levels ranging from a minimum of 5 years to a maximum of 70 years.

6.2 Acquisition of Land by Farmers in the Study Area:

The total cultivated area for farmers in the study sample averaged about 1.53 feddans, with a minimum of 0.06 feddans and a maximum of 18 feddans, regardless of ownership. The average area of owned agricultural land was about 1.4 feddans, and the area of leased agricultural land was about 0.13 feddans, with minimums of 0 feddans and maximums of 18 and 7 feddans, respectively. Table 4 shows that the number of cultivated wheat crop plots amounted to about 2296 plots, with an average of about 1.18 feddans, while the number of bean crop plots was 1140 plots, with an average of about 0.16 feddans, and minimums of 0 feddans and maximums of 18 and 10 feddans, respectively.

Table 2. Land Acquisition in Feddans of Farmers in the Study Area.

Land acquisition in feddans (fad)	Mean	Min	Max	SD
Total area cultivated (regardless of ownership).	1.53	0.058	18	1.44
The total area of agricultural land owned.	1.37	0	18	1.45
Area of agricultural land leased.	0.13	0	7	0.48
Total area of wheat.	1.18	0	18	1.27
The remaining area=Total area -Area of wheat.	0.34	0	10	0.85

Source: Field Survey Results.

6.3 Data for Assessing Dissemination Strategies:

When farmers were surveyed about the motivations behind their use of various dissemination methods, the leading reason for seeking information on modern variety recommendations was consistently ranked first across all methods: Training of Trainers, Farmer Field Schools, Video Screenings, Field Demonstrations, and Posters, with percentages of 63.2%, 58.6%, 40.8%, 40.4%, and 33.3%, respectively. This reason was second only to the harvest day, which had a percentage of 17.6%.

In addition, the interest in recommendations for fertilizers and irrigation components was ranked second for all methods (Video Screenings, Posters, Field Demonstrations, Farmer Field Schools, Training of Trainers), with percentages of 30.6%, 27.8%, 25.1%, 19.4%, and 16.8%, respectively. This reason was ranked fourth in importance when compared to the harvest day, which received a percentage of 7.8%.

Table 3. Reasons that Encouraged Farmers to Attend or Use Dissemination Methods.

Method	Farmer Field School (FFS)	Field demo	Training of Trainers	Video Screenings	Harvest Days	Posters
Reason 1	58.6	40.4	63.2	40.8	17.6	33.3
Reason 2	19.4	25.1	16.8	30.6	7.8	27.8
Reason 3	16	21	13.7	8.2	63.7	33.3
Reason 4	5.9	13.5	6.3	20.4	10.9	5.6
Total	100	100	100	100	100	100

Source: Field Survey Results.
Reason (1): Knowing the recommendations for modern varieties.
Reason (2): Knowing the recommendations for fertilizer and irrigation components.
Reason (3): Learn about planting and harvesting recommendations.
Reason (4): Get answers to the problems you face on your farm.

6.4 Impact Estimation and Treatment Effects of Improved Wheat Varieties:

Improving wheat varieties, such as Masr 3, Jamiza 12, and Beni Suef 5, contributes to increased productivity and quality, helping to meet the growing needs of the population. This is achieved through the use of advanced agricultural techniques and the application of innovative breeding methods.

The benefits of improving wheat varieties include increased resistance to diseases and pests, which reduces the need for chemical pesticides. Varieties like Masr 3, Jamiza 12, and Beni Suef 5 are specifically bred to enhance these characteristics, leading to better crop yields. Improved varieties can also lead to shorter growth periods, allowing farmers to cultivate additional crops during the growing season. Varieties that withstand harsh environmental conditions, such as drought or high temperatures, are essential in facing climate change.

Moreover, research and development in the field of variety improvement play a significant role in enhancing the competitiveness of farmers. By adopting improved wheat varieties, including Masr 3, Jamiza 12, and Beni Suef 5, farmers can boost their income and enhance the sustainability of their agricultural practices.

6.4.1 Impact on Yields (kg/ Fedan):

The findings from the ESR model highlight the factors influencing the adoption of improved wheat varieties, as previously discussed, along with the factors affecting the productivity of family farms. The lower section of Table 30 reveals that the estimated correlation coefficient Rho in the model is significantly different from zero, suggesting that unobservable factors contribute to sample selection bias. In particular, the negative value of Rho points to the presence of negative selection bias.

The results indicate in Table 4 a significantly positive relationship between both seed type and the amount of nitrogen fertilizer applied on yield, with a 1% significance level for both those who adopt improved wheat varieties and those who do not. In terms of productivity, non-adopters exhibited a positive and significant response to the quantity of TSP fertilizer used and weed control measures, highlighting the improved wheat varieties' resilience to weed competition and the lesser requirement for TSP fertilizer. Additionally, the influence of counterfactual governorates was found to be positively significant for adopters regarding wheat yield, whereas it had a negative and significant impact on the productivity of non-adopting farmers.

Table 4. Impact of the Adoption and Non-Adoption of Improved Wheat Varieties on Yields (kg/ Fedan):

Explanatory Variables	Yield Equation for Non-Adopter		Yield Equation for Adopter		Adoption of improved varieties (No=0, Yes=1)	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*	*Coef.*	*Std. Err.*
Area Fedan	0	0.006	-0.006	0.004	0.101	0.022***
Years of education(years)	-0.004	0.002**	-0.004	0.001***	0.011	0.005**
Farmer age (years)	0.006	0.011	0.002	0.007	-0.012	0.003***
Amount of seed used (kg/ Fedan)	0.226	0.010***	0.111	0.012***		
Quantity of TSP fertilizer used (kg/ Fedan)	0.004	0.001***	-0.001	0		
Quantity of nitrogen fertilizer used (kg/ Fedan)	-0.06	0.009***	-0.021	0.006***		
pest control	0	0.005	-0.003	0.003		
weed control	0.039	0.005***	-0.003	0.003		
Year (0= first year)	-0.007	0.004*	0.027	0.003***	0.387	0.058***
Counterfactual's governorates (1= non 4 project governorates)	0.037	0.005***	-0.014	0.003***	-0.272	0.067***
Number of visits to/by extension agents					0.076	0.024***
Number of visits to/by researchers					0.025	0.027
Farmer field school (FFS)					0.555	0.084***
Field demo					0.267	0.075***
Harvest Days					0.204	0.074***
Posters					-0.167	0.196
Training of Trainers					0.466	0.120***
Video Screenings					0.354	0.149**
Are you a member of the cooperative?					0.181	0.052***
_cons	7.127	0.078***	7.599	0.061***	-0.759	0.205***
Log likelihood	2149.2					
Rho	-0.323	0.093***	-0.84	0.046***		
sigma	-2.595	0.026***	-3.127	0.055***		
LR test of indep. eqns. chi2(2)	51.27***					

Source: Model Results.

6.4.2 Estimating Treatment Effects and Heterogeneity of Improved Varieties on Yield:

The following section compares the expected yield of farm households (a) with improved wheat varieties and (b) without improved wheat varieties. Additionally, we compare the expected yield of farm households with improved wheat varieties if they do not adopt (c) and farm households without improved wheat varieties if they adopt (d). This comparison encompasses the expected yield under both actual and counterfactual conditions.

Table 5. Average Expected Treatment and Heterogeneity Effects of Improved Varieties on Yield (kg/ Fedan).

Subsamples Effects	Adopter	Non-Adopter	Average Treatment
Farm households that adopted	(a) 2880	(c) 2521	359***
Farm households that did not adopt	(d) 2912	(b) 2426	486 ***
Heterogeneity effects	-32.5	94.8	-127.3***

Source: Model results.

The results are shown in Table 31. The expected yield of farm households that adopt improved varieties is 2880. Under the counterfactual condition, the expected yield of farm households that do not adopt improved varieties is 2521. The difference between these two yields reflects the average treatment effect (ATT) of the improved varieties, indicating the yield-increasing effect brought by the use of improved wheat varieties. The ATT is 359, suggesting that farms with improved varieties would reduce their expected yield by 14% if they did not adopt them. Conversely, if farms that currently do not adopt improved varieties (d) were to adopt them (b), the average treatment effect would be 486, indicating an expected yield increase of 20%.

As a result, the adoption of improved wheat varieties has a positive effect on farm households' yield, significant at the 1% statistical level. Furthermore, farm households that currently do not adopt improved wheat varieties would see a more significant increase in yield if they were to adopt, by 127. Therefore, it is recommended that farm households not currently adopting improved wheat varieties be encouraged to do so.

6.4.3 Impact on Net Income (kg/ Fedan):

The findings from the endogenous switching regression model (ESR) regarding net income are detailed in Table 6. For farmers who adopted improved wheat varieties, factors such as area per fedan, years of education, and farmer age were found to have a negative and statistically significant effect on net income. In contrast, for those farmers who did not adopt these varieties, the area per fedan similarly exhibited a negative and significant impact on net income; however, years of education and farmer age did not show any significant effects.

Moreover, both the quantity of seeds used and the amount of TSP fertilizer contributed positively and significantly to net income for farmers in both categories—adopters and non-adopters of improved wheat varieties. Conversely, the quantity of nitrogen fertilizer negatively and significantly affected net income for both groups.

Pest control positively and significantly influenced the net income of both farmers who adopted improved wheat varieties and those who did not. In contrast, while weed control had a positive effect on the net income of non-adopting farmers, it negatively and significantly impacted the income of adopters. Furthermore, the findings indicated that the second year (2021) positively and significantly affected the net income of those who adopted the improved varieties.

Table 6. Impact of The Adoption and Non-Adoption of Improved Wheat Varieties on Net Income (EGP/ Fedan):

Explanatory variables	Net Income Equation for Non-Adopter		Net Income Equation for Adopter	
	Coef.	*Std. Err.*	*Coef.*	*Std. Err.*
Area Fedan	-0.04	0.009***	-0.032	0.007***
Years of education(years)	-0.001	0.003	-0.012	0.003***
Farmer age (years)	0.016	0.017	-0.024	0.014***
Amount of seed used (kg/ Fedan)	0.253	0.016***	0.17	0.024***
Quantity of TSP fertilizer used (kg/ Fedan)	0.01	0.001***	0.002	0.001*
Quantity of nitrogen fertilizer used (kg/ Fedan)	-0.136	0.015***	-0.049	0.014***
pest control	0.012	0.007*	0.013	0.008***
weed control	0.023	0.008***	-0.023	0.007*
Year (0= first year)	-0.001	0.006	0.037	0.005***
Counterfactual's governorates (1= non 4 project governorates)	0.071	0.007***	-0.037	0.007***
_cons	8.782	0.122***	9.032	0.136***
Rho	-0.341	0.087***	-0.383	0.091***
sigma	0.118	0.003***	0.083	0.002***

Source: Model Results.

6.4.4 Estimating Treatment Effects and Heterogeneity of Improved Wheat Varieties on net income:

The results in Table 7 show the expected average treatment and heterogeneity effects on net income from the endogenous regression model estimates. In a notable comparison between adopters and non-adopters, we find that the net income per acre for agricultural families that adopted the improved wheat varieties is about 11,946 EGP per feddan, while agricultural families that did not adopt the varieties receive a net income of about 10,275 EGP per feddan. This indicates that farmers who adopted the improved wheat varieties would increase their net income per acre by about 16%. However, these results alone may be misleading.

Table 7. Average Expected Treatment and Heterogeneity Effects of Improved Wheat Varieties on Net Income (EGP/ Fedan):

Subsamples Effects	Adopter	Non-Adopter	Average Treatment
Farm households that adopted	(a) 11945.8	(c) 10469.3	1476.5***
Farm households that did not adopt	(d) 11680	(b)10275	1405***
Heterogeneity effects	266	194.3	71.6***

Source: Model Results.

A comparison of the observed results for adopters (A) with the contrasting results (C) reveals that the adoption of improved variety technology contributes to an increase in net income of approximately 1,477 EGP per feddan, equating to a 14% rise. Similarly, when examining the observed results for non-adopters (D) against the corresponding case (B), there is also a notable increase in net income per feddan by around 1,405 EGP, representing another 14% growth. These findings underscore the significant impact that adopting improved wheat varieties can have on enhancing farmers' net income.

6.4.5 Impact on Consumption:

The findings shown in Table 8 demonstrate the effect of adopting improved wheat varieties on wheat crop consumption. On average, wheat consumption per capita is approximately 92 kg.

Table 8. Impact of The Adoption of Improved Varieties on Wheat Consumption (kg/capita/year):

Explanatory variables	Coef.	Std. Err.
Technology (0,1)	0.229	0.034***
Area Fedan	-0.015	0.012
Years of education(years)	0.035	0.06
Farmer age (years)	0.246	0.032***
Amount of seed used (kg/ Fedan)	0.123	0.070*
Quantity of TSP fertilizer used (kg/ Fedan)	0.017	0.005***
Quantity of nitrogen fertilizer used (kg/ Fedan)	-0.235	0.056***
pest control	-0.095	0.029***
weed control	0.037	0.029
Year (0= first year)	-0.038	0.023
Counterfactual's governorates (1= non 4 project governorates)	0.224	0.031***
Number of visits to/by extension agents	-0.014	0.011
Number of visits to/by researchers	0.013	0.013
Farmer Field School (FFS)	-0.1	0.040***
Field demo	-0.1	0.037***
Harvest Days	0.079	0.034**
Posters	-0.227	0.093**
Training of Trainers	-0.04	0.059
Video Screenings	0.033	0.075
Are you a member of the cooperative?	-0.11	0.026***
_cons	4.656	0.474***

Source: Model Results.

The results reveal that the implementation of improved wheat varieties provided by the project has led to a roughly 23% increase in wheat crop consumption, equating to an additional 21 kg per capita. Furthermore, the analysis indicates that both the farmer's age and the application of TSP fertilizer have a positive and significant impact on wheat crop consumption. In contrast, the use of nitrogen fertilizer and pest control measures negatively affects wheat consumption.

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الملخص العربي

تقييم الأثر الاقتصادي لتبني التكنولوجيا الزراعية على تحسين إنتاجية القمح

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يُعتبر التطوير الزراعي قضية حيوية في العالم النامي، حيث أصبحت الحاجة إلى تحقيق نمو زراعي أسرع أمرًا ملحًا بشكل متزايد. في مصر، حيث يعمل القطاع الزراعي حوالي ٢٠.٣٪ من القوى العاملة ويساهم بنحو ١١٪ من الناتج المحلي الإجماليFAOSTAT) ، ٢٠٢٠(، يُعتبر تحسين إنتاجية القمح أمرًا أساسيًا. ومع ذلك، فإن الإنتاج المحلي من القمح لم يلبي سوى ٥١٪ من الطلب السنوي خلال الفترة من ٢٠٠٠ إلى ٢٠٢١.

تتطلب تحسينات الإنتاج الزراعي في مصر تبني ممارسات ديناميكية تشمل تكثيف الزراعة وتقليل الفاقد الغذائي. رغم التقدم، تظل المعلومات حول تكاليف وفوائد التقنيات الجديدة غير كافية، مما يخلق حالة من عدم اليقين لدى المزارعين. تهدف الدراسة إلى تحليل تبني التقنيات الزراعية وآثارها على المزارعين الصغار في مصر.

جمعت الدراسة بيانات على مرحلتين (٢٠٢٠/٢٠٢١ و٢٠٢٢/٢٠٢٣) من عينة تضم ١,٢٦٦ أسرة زراعية من عشر محافظات في مصر. أظهرت النتائج أن متوسط عمر المزارعين ٥٤ عامًا، ونسبة الذكور ٩٥٪ والإناث ٥٪. وكان لدى المزارعين متوسط خبرة زراعية قدرها ٢٥ عامًا، وحصلوا على المعلومات الزراعية من مصادر متعددة، مثل الإرشاد ومدارس المزارعين والهواتف المحمولة. على الرغم من أن ٩٩٪ من المزارعين كانوا جزءًا من جمعيات تعاونية، إلا أن ٣٥٪ منهم لم يشاركوا في هذه الجمعيات.

استخدمت الدراسة نموذج الانحدار المعتمد على التبديل الداخلي (ESR) لتقدير التأثيرات الاقتصادية للأصناف المحسنة من القمح. أظهرت النتائج أن تبني هذه الأصناف يزيد الإنتاج بمقدار ٣٥٩ كجم ويدعم دخل المزارع بمقدار ١٧٧٠ جنيهًا مصريًا للفدان مقارنة بعدم التبني. كما وُجد أن التبني يزيد استهلاك الفرد من القمح بنسبة ٢٣٪، ما يعادل زيادة بحوالي ٢١ كجم. توصي الدراسة الحكومة بتشجيع تبني الأصناف المحسنة وتسهيل الوصول إليها للمزارعين في جميع المحافظات.