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ARTICLE

Policy Impacts on Farm Efficiency: Fertilizer Subsidies in Corn Production in Madura Island, Indonesia

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ABSTRACT

This study aimed to analyze the effectiveness of the fertilizer subsidy policy and the impact of input use on corn production. The policy impact was measured using technical inefficiency in corn production. This study employed a case study on Madura Island, Indonesia. A total of 135 farmer respondents were selected using the multistage random sampling method. A series of analyses was conducted, incorporating the Cobb-Douglas Frontier Stochastic production function within the Technical Efficiency Impact Model. Five dimensions (planning, access via farmer cards, non-farmer cardholders, distribution, and the fundamental principles of ensuring the right quantity, right timing, right location, right price and right quality), derived from the Regulation of the Indonesian Ministry of Agriculture concerning the 2022 fertilizer subsidy policy, were used as the key measurements for assessing policy effectiveness. The results showed that the implementation of the fertilizer subsidy policy was in the effective category. The inputs that positively impacted corn production were land area, seeds, urea fertilizer, NPK fertilizer, manure, workers, and insecticides. Furthermore, the effectiveness of the fertilizer subsidy policy showed a positive impact on technical efficiency. This study can provide stakeholders with an overview of the effectiveness of the policy, serving as evaluation material. Improvements in production and technical efficiency after the change in fertilizer subsidy policy in corn farming on Madura Island can be achieved through the allocation of inputs according to recommendations. Additionally, enhancing the effectiveness of the fertilizer subsidy policy implementation can be considered a strategy to improve technical efficiency in corn farming.

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1. Introduction

Corn is an essential commodity with a strategic role as a food ingredient, feed, and industrial raw material for making fuel [1, 2]. Moreover, corn farming plays an important role as a primary source of income for millions of farmers' households [3]. The volume of corn trade has dominated the cereal trade in the global market due to the continuous rise in demand along with the increasing need for food and industry [4–6]. Despite the significant rise, increasing corn production to meet the high demand faces many challenges, including pest attacks [7], suboptimal land conditions, climate change [8], and increasing input costs [9]. Therefore, a strategy is needed to overcome these challenges. In Indonesia, various efforts have been made to encourage high corn production and overcome numerous challenges. These efforts include introducing superior varieties [10], extensification [11], and provision of financial assistance in the form of fertilizer subsidy that has been implemented since 1970 [12]. The purpose of providing the fertilizer subsidy policy is to increase agricultural production, achieve food security, and promote increased farmers' incomes, particularly in the food crop sector [13]. In Indonesia, this policy has undergone several changes in scheme and mechanism. The last change occurred in 2022, based on the Regulation of the Ministry of Agriculture Number 10 of 2022. The regulation explains that the types of fertilizer subsidy have changed from six to two types, namely urea and NPK (Nitrogen, Phosphorus, and Potassium). Meanwhile, the number of subsidized commodities has changed from 72 to 9 commodities (rice, corn, chili, soybeans, shallots, garlic, sugar cane, coffee, and cocoa).

Several other rules related to the mechanism for obtaining fertilizer subsidy in the Ministry of Agriculture regulation are the inclusion in farmers' groups and preparation of DPGN (Definitive Plan for Group Needs) in groups, accompanied by agricultural extensionists [14]. During the purchase of fertilizer subsidy, the Farmers Card is presented at official retailers. Meanwhile, farmers without a card can use the T-Pubers or REKAN (Retail Management System) application to redeem fertilizer subsidy [15]. This policy change is also expected to maximize the distribution of fertilizer subsidy, allowing easy purchase of fertilizer with close access. The distribution should also meet six precise principles, namely the right type, right amount, right time, right place, right price, and right quality [16]. These principles are often used as a benchmark for distribution effectiveness and as an evaluation instrument to provide fertilizer subsidy, particularly on Madura Island, Indonesia [15].

Madura Island makes a significant contribution to corn production, although the amount has decreased in the last two years. Empirically, facts have been found that low production can be caused by the use of inputs or sub-optimal factors. The decline in food crop farming production is a common problem, specifically in developing countries, including Indonesia. Various factors causing this problem include land conversion for non-agricultural needs, reaching 4.5% annually in Java [17, 18]. Furthermore, the decline is caused by climate change, environmental factors such as pests and diseases [19], inappropriate allocation of input use [20], socio-economic factors, and government policy, including fertilizer subsidy and price stabilization [21]. Several empirical studies state that urea and NPK fertilizer often positively impact corn production [22]. The level of productivity by farmers has not been able to reach the maximum potential due to the lack of input use and the inability to follow recommendations.

The problem of low production can also happen due to using fertilizer subsidies [23, 24]. Fertilizer subsidy has become the main instrument for the government in efforts to increase agricultural productivity, food security, and farmers' income, including in the corn commodity [25–27]. However, there are often problems that hinder the effectiveness of fertilizer subsidy policy during implementation. These include inappropriate policy design [28, 29], distribution [30, 31], as well as impact on agricultural productivity and sustainability [32, 33]. A preliminary study observed that farmers often experienced delays in obtaining urea fertilizer due to shortages. The use of the Farmers Card is also an obstacle, as the majority are unaware of banking procedures. Another problem is the limited provision of urea and NPK fertilizer, which does not correspond with the quantity requested in the DPGN submitted. These issues indicate shortcomings in the effectiveness of implementing fertilizer subsidy policy, which contributes to technical inefficiency [34, 35].

Technical efficiency (TE) is an important indicator to evaluate the performance of a farm and identify the gap between the current production level and the maximum potential output [36, 37]. Based on the definition, TE refers to the ability of farmers to maximize output using available inputs. In corn farming, TE is impacted by various factors, both positive and negative. Factors that can have a positive impact include higher levels of education and training, which equip farmers with the knowledge and skills to increase efficiency [38–40]. Other positive factors include larger farm sizes and the use of modern mechanization for more effective farming practices [36, 39], regular agricultural extension services that help farmers adopt the best method [41, 42], and the existence of the fertilizer subsidy policy [31]. Meanwhile, several factors with a negative impact on TE include high family dependency ratios that divert resources to non-productivity [40], and inclusion in activities outside the agricultural sector [36]. Other negative factors include errors in input management, such as excessive use of fertilizer and pesticides that can reduce efficiency and damage the environment [43].

Previous studies reported a strong relationship between production problems and fertilizer subsidy policy, particularly across five dimensions. These included DPGN, use of the Farmers Card, Non-Farmers Card, fertilizer distribution, and principles [44]. Measuring the effectiveness of the implementation of the fertilizer subsidy policy can be conducted by using the dimensions contained in the regulations, such as the principles of timeliness, quantity, price, quality, type, and distribution patterns [12, 31]. This process is very important to ensure that agricultural policy achieves the desired goals, namely increasing the technical efficiency and productivity of farming businesses [45–48]. Based on the background above, this study aimed to analyze the effectiveness of the 2022 fertilizer subsidy policy and the impact of input use on corn production after implementation. Furthermore, the impact of policy implementation was measured on the technical inefficiency of corn farming.

2. Materials and Methods

This study was conducted from September to December 2024 in Bangkalan and Pamekasan Regencies on Madura Island, Indonesia (**Table 1**).

Table 1. Location and Number of Study Samples.

Regency	Sub-District	Village	Number of Samples
Bangkalan	Blega	Lombang Dejeh, Nyormanis, Lomaer	45
	Burneh	Langkap, Tanjung, Arok	45
Pamekasan	Kadur	Kartagenah Tengh, Baung Baruh, Kadur	45

The respondents consisted of 135 farmers, determined using the multistage random sampling method. This evaluation was conducted by considering efficiency for large areas and increasing representation because samples were taken through several stages [49]. The first step was analyzing the effectiveness of the 2022 fertilizer subsidy policy based on five dimensions, namely DPGN, Farmers Card, Non-Farmers Card, Distribution of Fertilizer Subsidy, and Principles of Distribution (Kementerian Pertanian, 2022). Each dimension was measured using a scale of 1-3 (1 = not implemented, 2 = not implemented optimally, and 3 = fully implemented). Subsequently, effectiveness was categorized into five groups, namely very effective (80%–100%), effective (60%–80%), quite effective (40%–60%), ineffective (20%–40%), and very ineffective (0–20%). The second and third objectives were analyzed using the Cobb-Douglas stochastic frontier production function with the Maximum Likelihood Estimation (MLE) using Frontier 4.1 software [50, 51]. The stochastic frontier production function of the Cobb-Douglas type using MLE is expressed with the following equation:

$$\ln Y = \beta_0 + \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + \beta_4 \ln X_4 + \beta_5 \ln X_5 + \beta_6 \ln X_6 + \beta_7 \ln X_7 + \beta_8 \ln X_8 + \beta_9 \ln X_9 + (vi - ui) \quad (1)$$

Description: Y: Corn Production (Quintal); X_1: Land area (Ha); X_2: Amount of corn seeds (Kg); X_3: Amount of Urea Fertilizer (Kg); X_4: Amount of NPK Fertilizer (Kg); X_5: Amount of ZA (Kg); X_6: Amount of manure (Kg); X_7: Amount of Insecticide (Ml); X_8: Amount of workers (workdays); X_9: Amount of Herbicide (Ml); β_0 is the Intercept/Constant; β_1–β_9: Regression coefficient; v_i is a systematic error component, a symmetric, normally distributed random error or random error model, and ui shows a one-side error term ($U_i \geq 0$) or technical inefficiency. Technically, the hypothetical Cobb-Douglas Stochastic Frontier Function Model is formulated as follows:

H0. $\beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6 = \beta_7 = \beta_8 = \beta_9 = 0$

H1. $\beta_{i-9} \neq 0$

To measure TE, econometric methods such as stochastic frontier analysis (SFA) have been proven effective in various sectors. The SFA method helps estimate the efficiency of production units by separating random errors from the impact of inefficiency, thereby providing a more accurate measure of TE [52]. Some of the widely used SFA methods are multiple technical efficiency (MTE), Bayesian, Translog, and Panel Data Analysis [53, 54]. These methods consider flexibility in handling different data structures and stochastic variations, showing potential as valuable tools for studies and policymakers to improve productivity and efficiency. Additionally, SFA can accurately separate technical inefficiency from random factors in agricultural production, leading to more appropriate decisions and better agricultural management practices [55]. The use of the Frontier program version 4.1, in addition to producing TE results for production factors, also delivers an analysis of technical inefficiency impact in the form of parameter estimates (u_i) with the following equation:

$$U_i = \delta_0 + \delta_1 Z_1 + \delta_2 Z_2 + \delta_3 Z_3 + \delta_4 Z_4 + \delta_5 Z_5 + \delta_6 Z_6 + \delta_7 Z_7 + \delta_8 Z_8 + \delta_9 Z_9 + \delta_{10} Z_{10} + \delta_{11} Z_{11} + e_i \quad (2)$$

Description: Z_1: Age (years); Z_2: Experience in farming (years); Z_3: Education (years); Z_4: Off-farm income (0 = have, 1 = do not have): Z_5: Frequency of Agricultural Extension in one planting season; Z_6: Irrigation system (0= technical, 1= non-technical); Z_7–Z_{11} respectively show the average score of effectiveness of fertilizer subsidy policy implementation in the dimensions of DPGN, Farmers Card, Non-Farmers Card, distribution of fertilizer subsidy and principles of fertilizer subsidy distribution; u_i shows the impact of technical inefficiency. Hypothetical tests within the technical inefficiency model are explained as follows:

H0. $\delta_1 = \delta_2 = \delta_3 = \delta_4 = \delta_5 = \delta_6 = \delta_7 = \delta_8 = \delta_9 = \delta_{10} = \delta_{11} = 0$

H1. $\delta_{i-11} < 0$

Technical inefficiency in farming refers to a condition in which farmers are unable to achieve maximum output from the inputs they use. A high level of technical inefficiency indicates that the farmer's technical efficiency is low, and vice versa. Thus, attaining high technical efficiency is crucial for maximizing production with the given inputs, which in turn helps reduce technical inefficiency [20, 34, 35, 38–40]. Achieving high technical efficiency reflects a low degree of technical inefficiency.

3. Results

3.1. General Characteristics of Respondents

The characteristics of corn farmers in Madura Island, as presented in **Table 2**, generally align with those observed in developing countries [31, 56, 57]. The majority belong to the productive age group, averaging 50 years old; however, a high standard deviation indicates a wide range of ages, from younger to older generations. While male farmers constitute the majority of respondents, a significant number of female farmers are also present. In terms of education, most farmers have completed elementary school, although some have a high school background. This educational level influences their ability to adopt modern agricultural technologies. Regarding experience, farmers have, on average, 24 years of involvement in corn farming. While extensive experience supports farm management, it may also pose limitations on innovation if not accompanied by ongoing knowledge updates. Additionally, most farmers are married and typically support a household of four dependents. Beyond farming, they engage in off-farm work, which serves as a supplementary source of income to sustain their families and farming activities.

Table 2. Characteristics of Farmer Respondents in Madura Island, Indonesia.

Variable	Average	Standard Deviation
Age (years)	50.14	14.27
Gender (1 = male; 0 = female)	0.64	0.48
Education (years)	6.16	2.84
Experience (years)	24.39	14.04
Marriage Status (1 = married; 0 = single)	0.95	0.23
Number of family members (person)	4.17	2.11
Off-farm job (1 = Yes; 0 = No)	0.60	0.50

3.2. Effectiveness Level of the 2022 Fertilizer Subsidy Policy Implementation

In this study, the effectiveness of implementing the fertilizer subsidy policy was evaluated using five dimensions (**Figure 1**). These included DPGN, Farmers Card, Non-Farmers Card, distribution of fertilizer subsidy, and the principle of distribution.

The effectiveness of implementing the fertilizer subsidy policy is in the effective category, with a score of 65.87%. The use of the Non-Farmers Card is a very effective dimension, holding a score of 92.33, which is inversely proportional to the Farmers Card (with a score of 35.13). Card use is a component of fertilizer subsidy policy that cannot be implemented due to the system's unpreparedness and the conditions of recipients. Therefore, the Farmer Card ranks as the least effectively implemented component. The next highest priority is the Definitive Plan for Group Needs, with an implementation rate of 75.67%, followed by the distribution process (66.67%) and the application of distribution principles (59.57%).

DPGN is an initial procedure that is carried out when farmers want to get the fertilizer subsidy. The procedure serves as a plan for the need for agricultural production facilities, machinery for one season/business cycle, and fertilizer subsidy needs. This plan is typically prepared based on a discussion with the members of the farmers' group [58]. In the preparation of DPGN, there are several indicators used, namely (1) socialization of subsidy policies by agricultural extensionists, (2) farmers' inclusion in preparing DPGN, (3) assistance in preparation by agricultural extensionists, and (4) awareness of the DPGN draft prepared by the farmers' group. The effectiveness of fertilizer subsidy policy implementation based on dimensions of Definitive Group Needs Plan (DPGN) is shown in **Figure 2**.

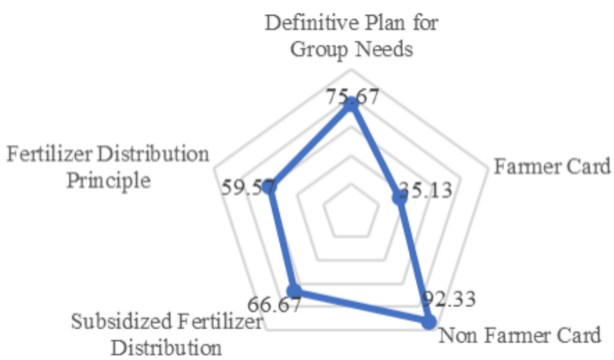

Figure 1. Effectiveness Level of Implementation of Fertilizer Subsidy Policy on Madura Island, Indonesia.

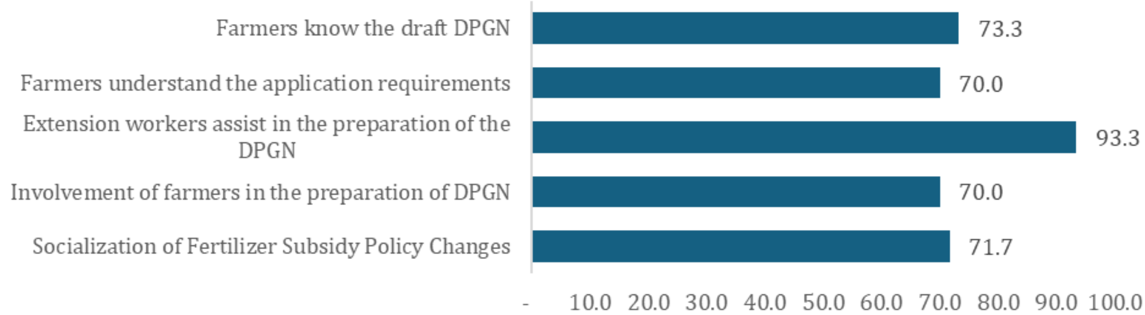

Figure 2. The Effectiveness of Fertilizer Subsidy Policy Implementation Based on Dimensions of Definitive Group Needs Plan (DPGN).

Based on the results of DPGN dimension indicators (**Figure 2**), the effectiveness of the implementation of the fertilizer subsidy policy was in the effective category. This effectiveness level was supported by the indicator of the active role of Agricultural Extension Workers in compiling DPGN. The presence of extension workers is very important in this process due to their activity in socialization. Therefore, farmers understand the economic, resource, and environmental benefits of using fertilizer effectively[59, 60]. Farmers' needs are noted through an electronic system called e-DPGN. Input into the system is not possible for farmers due to a lack of application caused by an average low level of education (78% have an elementary school education), and 62% of farmers are over 50 years old.

In line with the results, 92% of respondents stated that agricultural extension workers were always present to assist farmers' groups in submitting DPGN. The activity of extension workers at the study location supports the effectiveness of other indicators in the DPGN dimension. Approximately 75% of respondents stated that the socialization carried out by agricultural extensionists had an impact on the understanding of requirements for submitting fertilizer subsidy and knowing the DPGN draft prepared by the group.

The second dimension used to assess the effectiveness of fertilizer subsidy policy is the use of the Farmers Card. This card serves as access to banking services in physical or electronic/digital form that functions as a transaction tool for redeeming fertilizer subsidy at official retailers. However, the program has high complexity due to the inclusion of several related agencies, namely the Coordinating Ministry for the Economy, the Ministry of Home Affairs, the Ministry of State-Owned Enterprises, the Ministry of Trade, the Ministry of Finance, the Ministry of Agriculture, the Governor, and the Regent/Mayor. Based on the results (**Figure 3**), the use of the Farmers Card was not effective in implementing the fertilizer subsidy policy. Aside from that, the Farmers Card was not an obligation to redeem fertilizer because, in the Decree of the Directorate General of Facilities and Infrastructure of the Ministry of Agriculture, farmers were still allowed to redeem fertilizer without using the card.

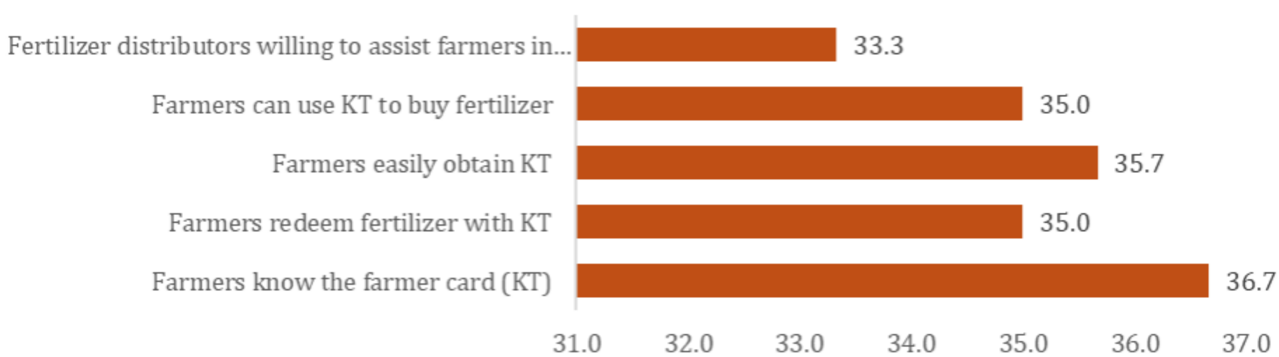

Figure 3. The Effectiveness of Fertilizer Subsidy Policy Implementation Based on the Dimension of Farmers' Card Use.

There are two mechanisms for redeeming the fertilizer subsidy without using the Farmers Card, namely, the T-Pubers application and the Rekan application. These applications can simplify the process, reduce misuse, and increase efficiency [57, 61, 62]. The difference between the mechanisms is in the party redeeming fertilizer subsidy. In the T-Pubers application, farmers carry out fertilizer subsidy redemption independently. Meanwhile, in the Rekan application, the redeemer at the official retail kiosk is the Head of the Farmers Group, who members of the Farmers Group will then redeem. This is conducted because farmers have constraints, including health factors, old age, force majeure, and limited transportation. Based on the analysis results in **Figure 4**, more than 90% of fertilizer redemption was carried out using the Non-Farmers Card. This showed that the redemption method with the two applications was very effective. Approximately 95% of respondents admitted to redeeming fertilizer subsidy independently or through groups. This was conducted to ease the redemption process, without going through complicated administrative procedures, such as using a Farmers Card.

The fourth dimension used to measure effectiveness is the distribution of the fertilizer subsidy. In this study, fertilizer subsidy distributors consist of four lines, namely producers (lines I and II), distributors (line III), and retailers who deal directly with farmers (line IV).

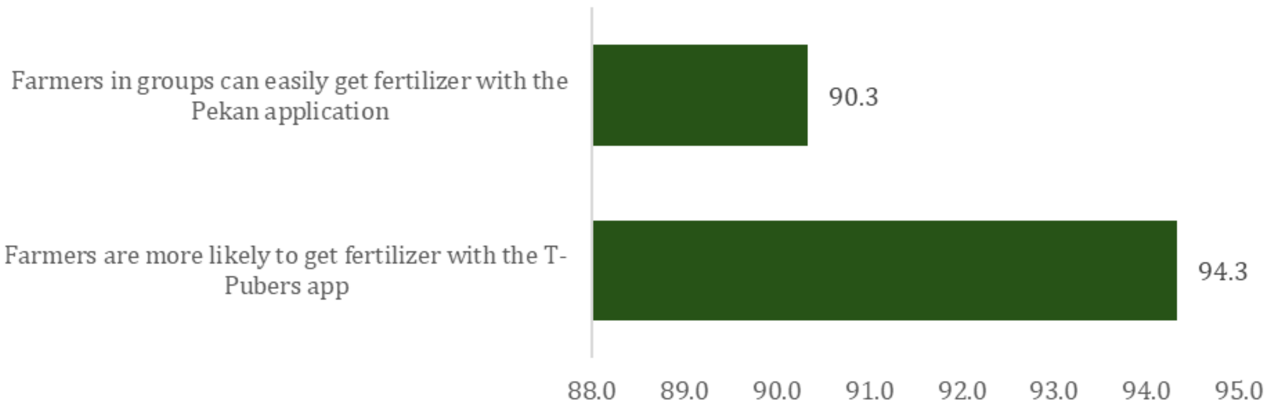

Figure 4. The Effectiveness of Fertilizer Subsidy Policy Implementation Based on the Dimensions of the Use of Non-Farmers' Card.

The effectiveness of fertilizer subsidy distribution is assessed from the services provided by line IV distributors (**Figure 5**). The indicators used are reliable distributors in serving farmers, provision of convenience in service, clear information to farmers, and easy accessibility. Based on these four indicators, the implementation of the fertilizer subsidy policy is considered effective (**Figure 5**). However, the effectiveness score (66.67) is still close to the minimum limit of the effective category (60–80 %). Approximately 43 % of respondents assessed that fertilizer subsidy distributors still did not meet expectations in terms of reliability, openness of information, and ease of service. This served as a signal that fertilizer subsidy distributors still needed to improve the services provided. Reliability, informativeness, and affordability could encourage improvements in the distribution process, as well as ensure that farmers obtain fertilizer on time and efficiently [56, 63].

The principle of fertilizer subsidy distribution is the fifth dimension to measure the effectiveness of the implementation. The six principles of this dimension, according to the Decree of the Directorate General of Agriculture, are the right quality, price, place, time, amount, and type. Based on the results of the analysis, it was found that the principles fulfilled were the right type and quality (**Figure 6**). However, the others still needed to be improved, namely the principles of price, place, time, and amount.

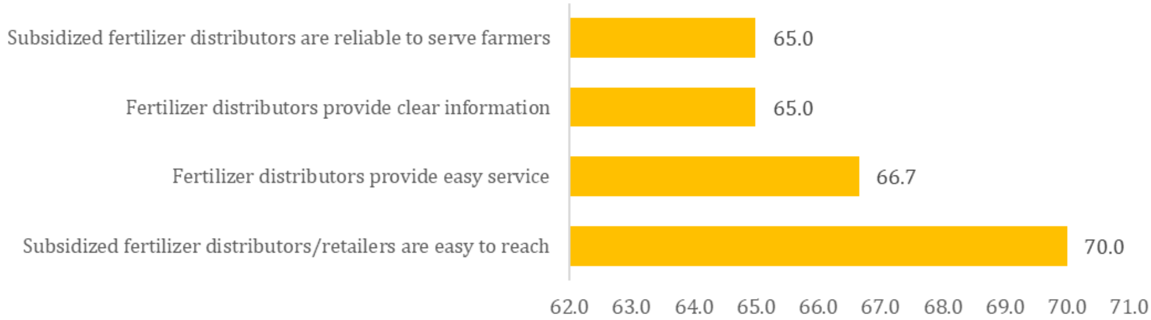

Figure 5. Effectiveness of Implementation of Fertilizer Subsidy Policy Based on Fertilizer Subsidy Distribution Dimensions.

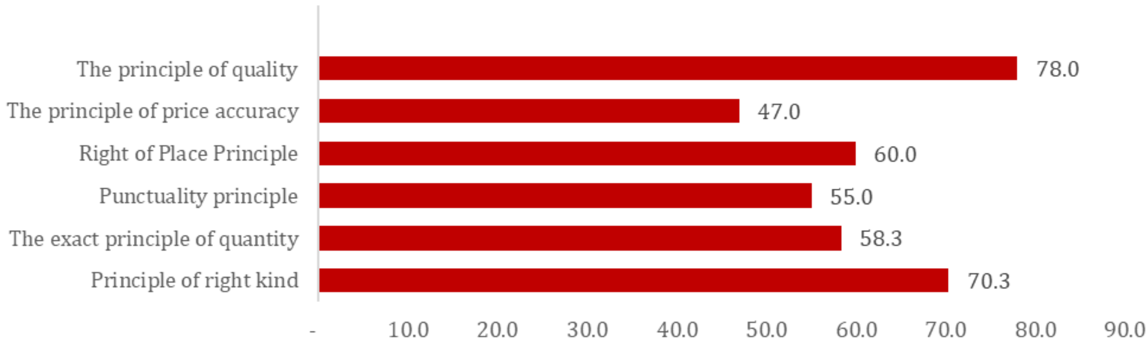

Figure 6. Effectiveness of Implementation of Fertilizer Subsidy Policy Based on the Dimensions of Fertilizer Subsidy Distribution Principles.

3.3. The Impact of Input Use on Corn Production After the 2022 Fertilizer Subsidy Policy

The Cobb-Douglas Frontier Stochastic production function is widely used to analyze the TE level of various commodities in the agricultural sector. Before analyzing the level of efficiency of corn farming after the change in the 2022 fertilizer subsidy policy, the impact of input use was evaluated. The results revealed that seven input variables had a significant influence on corn production—namely land area, seeds, urea fertilizer, NPK fertilizer, manure, insecticides, and labor—thereby rejecting the null hypothesis (**Table 3**). A 1% increase in land area led to a 0.131% rise in corn output; a 1% increase in seed use resulted in a 0.256% increase in production. Similarly, a 1% rise in urea fertilizer contributed to a 0.126% increase, while NPK fertilizer showed a 0.156% increase in output for every 1% increment. An increase of 1% in manure use led to a 0.187% rise in production, and a 1% increase in labor boosted productivity by 0.052%. Meanwhile, the input of ZA fertilizer and herbicides included in the model did not have a significant impact on corn production.

Table 3. Determinant Factors of Corn Farming Business After Implementation of Fertilizer Subsidy Policy.

Variables	Coefficient	Standard Error	t-Ratio	Sig.
Constant	3.456	0.192	18.000	
Land (X1)	0.131	0.025	5.240	*
Seed (X2)	0.256	0.087	2.943	*
Urea (X3)	0.126	0.038	3.316	*
NPK (X4)	0.156	0.009	17.333	*
ZA (X5)	0.002	0.178	0.011	NS
Manure (X6)	0.187	0.021	8.905	*
Insecticide (X7)	0.034	0.012	2.833	*
Workforce (X8)	0.052	0.024	2.167	*
Herbicide (X9)	0.056	0.127	0.441	NS

Table 3. *Cont.*

Variables	Coefficient	Standard Error	t-Ratio	Sig.
Sigma-Squared	0.224	0.016	14.000	*
Gamma	0.999	0.011	90.818	*
OLS log-likelihood	−40.675			
MLE log-likelihood	−20.987			
LR test	39.376			

Note: * degree of error (α) is 1%.

3.4. The Impact of the Effectiveness of Fertilizer Subsidy Policy on Technical Inefficiency of Corn Farming

The level of TE shows how much farmers can produce output close to the highest potential. The greater gap between real output and output at the highest potential corresponds to less efficiency among farmers. In this study, the level of efficiency is expressed in the range of 0.00 to 1.00. Farmers are said to be efficient when the value is 0.8 to 1. Based on this range, 74.8% of corn farmers are in the inefficient category, achieving an average efficiency level of 0.42 (**Table 4**). However, there are 34 respondents who can produce efficiently, with the highest level of 0.965. Farmers who were able to achieve the highest TE used an average of certified seeds, urea fertilizer, NPK, manure, and insecticides of 22.5 Kg/Ha, 25.3 Kg/Ha, 52.4 Kg/Ha, 1.87 tons/Ha, and 1.5 liters/Ha, respectively.

The TE level achieved by farmers shows the behavior of allocating inputs in corn farming. Based on **Figure 7**, the greater gap between the allocation of inputs used and the recommendations corresponds to less efficiency. The use of seeds, urea, NPK, manure, and insecticides by corn farmers is below the recommended levels. The recommended amounts are: 25 kg of seed, 30 quintals of urea, 35 quintals of NPK, 50 quintals of manure, and 2 liters of insecticide.

Table 4. Corn Farming Efficiency Level.

Technical Efficiency Level	Total of Farmers	Percentage(%)
≤0.50	10	7.4
0.51–<0.60	40	29.6
0.60–<0.70	34	25.2
0.70–<0.80	17	12.6
0.80–<0.90	19	14.1
0.90–1.00	15	11.1
Total	135	100.0
Average	0.420	
Maximum	0.965	
Minimum	0.159	

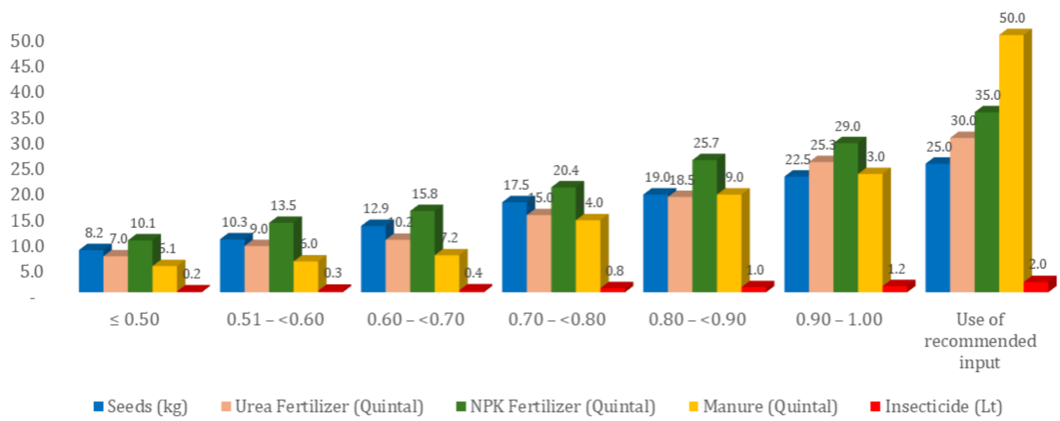

Figure 7. Average Allocation of Several Inputs to Various Categories of TE Achievement.

Meanwhile, socio-economic factors that impact technical inefficiency include age, education level, off-farm income, and frequency of agricultural extensionists (shown in **Table 5**).

Farmer age and off-farm income are positively associated with technical inefficiency, indicating that older farmers and those engaged in off-farm employment tend to be less efficient. In contrast, variables such as education level and frequency of extension counselling are negatively associated. This suggests that improvements in these areas contribute to reducing inefficiency or promoting improvements in technical efficiency. Next, a description of the condition of socio-economic factors when associated with achieving the level of TE is shown in **Figure 8**.

Table 5. Impact of Effectiveness of Fertilizer Policy Implementation on Technical Inefficiency.

Variable	Coefficient	Standard Error	*t* Rasio	Sig.
Constant	0.245	0.042	5.833	
Farmer's age (Z1)	0.279	0.071	3.930	*
Farming experience (Z2)	−0.023	0.019	−1.211	NS
Education (Z3)	−0.273	0.068	−4.015	*
Off-farm Income (Z4)	0.023	0.013	1.769	**
Frequency of extension (Z5)	−0.939	0.325	−2.889	*
Irrigation system (Z6)	−0.423	0.319	−1.326	NS
Definitive Plan for Group Needs of effectiveness score (Z7)	−0.231	0.104	−2.221	*
Farmers Card effectiveness score (Z8)	0.004	0.078	0.051	NS
Non-Farmers Card effectiveness score (Z9)	−0.151	0.067	−2.254	*
Fertilizer subsidy distribution effectiveness score (Z10)	−0.232	0.096	−2.417	*
Principles of fertilizer subsidy distribution effectiveness score (Z11)	−0.034	0.012	−2.833	*

Note: * significant at 95% ($p < 0.05$), ** significant at 90% ($p < 0.1$).

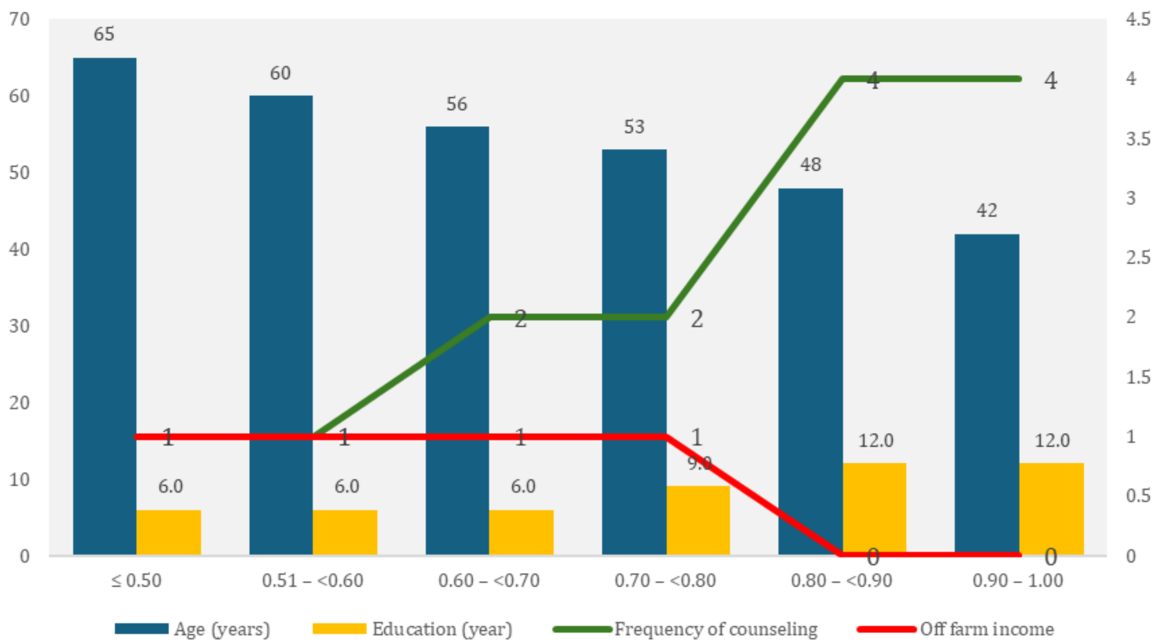

Figure 8. Description of Socio-Economic Factor Conditions Based on TE Achievements.

Figure 8 presents the categorization of technical efficiency (TE) based on respondents' characteristics. Farmers with a TE of less than 0.05 are typically under 65 years old, have approximately six years of education, attend counseling sessions once, and earn off-farm income. Similarly, those with a TE between 0.51 and 0.60 are generally around 60 years old, attend one counseling session, and also receive off-farm income. Farmers with a TE between 0.60 and 0.70 tend to be 56 years old, have six years of education, attend two counseling sessions, and earn additional off-farm income. Farmers with a technical efficiency (TE) between 0.70 and less than 0.80 are typically 53 years old, have nine years of education, attend two counseling sessions, and earn additional off-farm income. In contrast, respondents with TE greater than 0.80 are generally in their 40s, have more than 12 years of education, attend four counseling sessions, and do not earn any additional off-farm income.

Furthermore, fertilizer subsidy policy, measured through variables such as the effectiveness of implementing the DPNG dimension, the use of Non-Farmer Cards, the distribution of subsidized fertilizers, and the application of subsidy allocation principles, has a negative effect on technical inefficiency. This implies that the more effectively these dimensions are implemented, the lower the technical inefficiency, or in other words, the higher the technical efficiency. In addition to this, based on the data analysis described earlier, the effectiveness scores of these four dimensions are not yet categorized as "very good," indicating there is still room for improvement. Enhancing the effectiveness of these variables could help reduce farmers' inefficiency and increase their efficiency. In this regard, timeliness and price accuracy are particularly crucial in the fertilizer subsidy policy. Farmers often do not receive fertilizer at the government-regulated price, and instead pay a higher price, limiting the quantity they can afford. Additionally, fertilizer is frequently delivered outside the optimal fertilization period, reducing its effectiveness. These issues contribute to lower production levels and reduced technical efficiency.

4. Discussion

Based on the five dimensions of measuring the effectiveness of implementing fertilizer subsidy policy, the effectiveness of implementing fertilizer subsidy policy is generally included in the effective category, although the score is still at the lower limit. Several dimensions that need to be prioritized for improvement are the use of the Farmers Card and the principles of distributing fertilizer subsidy. The low effectiveness of the Farmers Card is a signal that the method of redeeming fertilizer by including banks is still a significant obstacle for farmers. This is because approximately 97% of farmers do not recognize the Farmers Card. The results were in line with findings from studies by Rondhi and Nanda; and Magfiroh et al.[64, 65], where the use of the Farmers Card was difficult to implement because data in the field was considered invalid and incomplete. Furthermore, there were limitations in equipment and infrastructure, low knowledge/education of farmers, experience, and the role of agricultural extensionists. Therefore, the existence of the card has received fewer positive responses in policy implementation. Banking is also difficult for farmers in remote/isolated locations to access because most banks are in cities. The unpreparedness of farmers in using the Farmers Card needs to be re-evaluated by the government. The second dimension that needs attention is the principle of fertilizer subsidy distribution. Based on the analysis, 70% of respondents stated that the quality and type of fertilizer provided had met the established standards. From the principle of right price, there are still many farmers who have to pay fertilizer prices above the Highest Retail Price. This is particularly true for farmers who use the 'Rekan' application, because of the payment for additional transportation costs. According to the explanation of several farmers' groups, the fertilizer needed is often not available on time due to the limited distribution of kiosks[31, 56, 57]. Inaccuracy of time is caused by high logistics costs[63], and will impact the level of crop productivity[56]. A principle that is also often overlooked is the right amount. This is shown by the difference in the amount of fertilizer that can be redeemed with DPGN submitted by farmers. Some explanations obtained in the field are that the amount of fertilizer redeemed by farmers is less than the amount in the redemption plan. As stated by the head of the farmers' group, only 61.5% of the fertilizer submitted in the DPGN is obtainable.

Based on the results of the Cobb-Douglas production function analysis, the low level of corn production is caused by several factors, including land size, seed usage, urea and NPK fertilizers, organic manure, labor input, and insecticide application. The land is a fundamental requirement for agricultural production, serving as the foundation upon which crops are cultivated and yields are determined. An increase in land area enables farmers to scale up their operations, allowing for the cultivation of larger corn fields and the implementation of more efficient farming techniques. This is an indicator that corn farmers can improve productivity through an increase in land area. Similar results were reported in previous studies by Ren et al. (in 2014), Aragon (in 2019), and Vo (in 2020), which highlighted land as a critical asset for increasing productivity [66–68]. However, the process is not easy, considering that farmers included in the smallholder category have an average land area of 0.32 hectares. There are many problems with the conversion of agricultural land for non-agricultural needs, such as industry and housing. To address this problem, a strategy that can be carried out is that farmers can collaborate with others who have adjacent land. The collaboration reduces costs, increases crop efficiency and productivity, and improves agricultural sustainability [69–72]. Additionally, the use of vacant land owned by the local government can be applied to increase corn production. Next, the quantity and quality of seeds play a crucial role in determining the overall yield and crop performance. High-quality seeds contribute to better germination rates and resistance to pests and diseases, ultimately leading to improved productivity and profitability for farmers. Additionally, the quantity of seeds used is directly linked to planting density, which affects crop uniformity and yield potential. Despite the importance of seed selection, current usage among farmers remains limited. Based on the recommendations of agricultural extensionists, the number of seeds that should be used for corn production per hectare was an average of 20–25 Kg/Ha. However, the average number of seeds used at the study location was 15.16 Kg/Ha. According to the explanation of the head of the farmers' group, farmers have used the number of seeds based on farming experience and limited financing to buy certified seeds characterized by a significant contribution to productivity [73].

Next, despite their positive impact, Urea and NPK remain underutilized by farmers, with usage levels still falling below recommended guidelines. While the recommended dose is 250–300 Kg/Ha, the amount used by farmers on average is 142 Kg/Ha due to the unavailability of fertilizer subsidy. In fact, farmers receive fertilizer subsidy quotas in smaller amounts than those proposed in DPGN. Therefore, some farmers often buy non-fertilizer subsidies, which are more expensive. Urea fertilizer is critical since it is one of the determining factors for plant growth and production due to its ability to stabilize soil aggregates, humic acid content, and plant nitrogen absorption, thereby increasing corn yields [74–76]. Similar to those in Urea, NPK fertilizer is also a production factor that has a positive impact. The provision of NPK fertilizer serves to increase growth, productivity, and nutrient availability [77–79]. Based on good corn cultivation methods, the NPK requirement per hectare is 300–350 Kg/Ha. In practice, the average farmers only use NPK from the recommended amount, which is 197 Kg/Ha, because of a situation identical to the case of using urea fertilizer.

Next, the use of manure also shows a positive impact, where it is carried out by farmers as an effort to replace the lack of urea and NPK fertilizer. Manure is a very useful resource for improving soil fertility, increasing crop yields, and supporting sustainable agriculture [80–82]. Integration of manure into nutrient management plans can improve soil health and long-term agricultural productivity. In the study location, many farmers raise cattle, and the dung is dried to be used as manure. Based on the analysis, manure has a positive and significant impact, with a potential increase of 5 tons/ha at an average use of 1.24 tons/Ha. Despite the sub-optimal use, the provision of manure is relatively abundant as a cheap and environmentally friendly alternative [83].

The insecticide factor also has a positive and significant impact, with an average use of 0.62 liters per hectare. Insecticides function to control pests that can reduce plant productivity and prevent diseases whose vectors are insects. Several types of insects that are often pests at the study location include grasshoppers, seed flies, armyworms, stem borers, and corn cob borers, showing the need for 1–2 liters of insecticide per hectare. Several farmers have carried out integrated pest control, namely combining the use of insecticides and physical pest control through superior varieties, weeding, and soil cultivation to reduce excessive costs. Impact of environmental degradation due to excessive use of insecticides can also be controlled [84–86].

The last factor that plays an important role in corn production is the use of workers. Corn farming in the study location mostly includes family members, as wage workers are only used during the harvest season. This labor structure has both advantages and limitations. Family labour ensures cost efficiency, as it reduces the financial burden of hiring external workers. Additionally, family members often have a deep understanding of the land and farming techniques, contributing to better crop management. However, reliance on family labor can also limit productivity, as seasonal demands such as planting, weeding, and fertilization may require more manpower than is readily available within the household. On average, intensive work is carried out during the planting and the harvest season. Corn plant maintenance is rarely carried out because approximately 71.85% of farmers also have other jobs in different farming, such as construction workers, motorcycle taxi drivers, factory workers, small traders, and others. The allocation of input use in corn farming that has not yet resulted in maximum output can serve as an indicator of the level of technical efficiency or inefficiency. Four elements have a negative impact on reducing technical inefficiency, namely DPGN, Non-Farmers Card, fertilizer distribution, and the principle of fertilizer subsidy distribution. This suggests that as the effectiveness of DPGN preparedness increases, the level of inefficiency of corn farming decreases. In other words, the more effective the implementation of the DPGN, the greater the technical efficiency of corn farming. Based on the analysis, the effectiveness of DPGN is classified as effective. However, there are indicators that can still be used for improvement, such as increasing the active participation of farmers during preparation. Explanation from the head of the farmers' group shows high participation in DPGN, but many are still passive. Additionally, the effectiveness of fertilizer subsidy distribution is a factor that can reduce the level of inefficiency. This shows that the more effectively the fertilizer subsidy is distributed, the higher the efficiency that can be achieved.

The results of the effectiveness assessment on this dimension are effective, but the score is still close to the lower threshold. Several indicators that can be improved include ease of service, clarity of information provided, and professionalism of fertilizer subsidy retailers [57, 87, 88]. When the effectiveness of these four dimensions is increased, it can reduce the level of technical inefficiency or increase technical efficiency.

The implications of this study include an increase in the effectiveness of implementing fertilizer subsidy policy as a consideration to reduce the level of technical inefficiency or improve TE in corn farming on Madura Island, Indonesia. The achievement of TE levels by farmers is impacted by socio-economic, managerial, and government policy factors [89, 90]. Therefore, future policies could focus on variables such as frequency of extension counselling, implementation of the Definitive Plan for Group Needs (DPNG), use of Non-Farmer cards, effective distribution of fertilizer subsidies, and adherence to the principles of fertilizer subsidy implementation. Facts in the field show that farmers' participation in extension activities has a negative impact on inefficiency. Extension activities in the field are carried out on average four times in one planting season, and group meetings are held. These include preparation of DPGN twice, technical assistance for cultivation, and support when there are problems related to corn farming. Most farmers (68%) only attend meetings during the preparation of DPGN, which concerns the need to access fertilizer subsidy. Various forms of improvement that can also be made are the inclusion of farmers more intensively in the preparation of DPGN, and increasing fertilizer subsidy distribution by improving reliability. Furthermore, the ability to provide clear information is essential, including easy accessibility for fertilizer subsidy agents at the right place, time, price, and quantity. Improvements in the TE of corn farming can also be performed through the use of inputs according to recommendations. The addition of seeds, urea fertilizer, NPK, manure, insecticides, and workers' input still needs to be improved. However, efforts that have been made by farmers to start using environmentally friendly inputs and integrated pest control should be continued to get support. There is also a need to improve the socio-economic conditions, such as optimizing the presence of farmers in agricultural extensionists' agricultural extension activities and using part of the off-farm income for the on-farm needs of corn farming.

5. Conclusions

The implementation of the fertilizer subsidy policy on Madura Island, Indonesia, is in the effective category. The use of the Non-Farmers Card is the most effective dimension, while the use of the Farmers Card is the least effective. The inputs that have a significant positive impact on corn production are land area, seeds, urea fertilizer, NPK fertilizer, manure, insecticides, and labor. The effectiveness of the fertilizer subsidy policy has a negative impact on technical inefficiency, indicating that improvements in the implementation of the policy can help increase TE. Socio-economic factors such as age, education level, off-farm income, and frequency of agricultural extensionists also impact technical inefficiency.

Based on the results of this study, several recommendations can be proposed. First, the government needs to improve the effectiveness of the implementation of the fertilizer subsidy policy, especially in the dimensions of distribution and principles. Second, farmers need to use inputs in accordance with recommendations to achieve maximum production. Third, farmers need to improve their education level and participate in agricultural extension activities to increase their TE. Fourth, the government needs to provide assistance and training to farmers regarding the use of the T-Pubers and REKAN applications to simplify the process of redeeming fertilizer subsidy.

Author Contributions

Conceptualization, E.F.; methodology, E.F.; validation, E.F., and D.R.H.; formal analysis, E.F., and I.M.; investigation, E.F., and D.R.H.; data curation, E.F., and I.M.; writing—original draft preparation, I.M.; writing—review and editing, D.R.H.; visualization, I.M.; supervision, E.F. All authors have read and agreed to the published version of the manuscript.

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Informed Consent Statement

Informed consent was obtained from all participants involved in the study's survey.

Data Availability Statement

Data will be made available on request.

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Conflicts of Interest

The authors declare no conflict of interest.

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