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The Impact of Information and Communication Technology (ICT) on Pesticides Use of Potato Farmers in Indonesia

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Abstract

Reducing pesticides is an important driver in preserving a healthy and sustainable environment and protecting human health. In the digital era, understanding the role of information and communication technology (ICT) on pesticide use in crucial. Therefore, This study aim to estimate the impact of ICT on farmers' pesticide used. This study uses a cross-sectional data from a survey to 150 farmers in Indonesia. Furthermore, the data is analyzed by ordinary least square (OLS) and instrumental variable quantile regression (IVQR). The main results indicate that ICT has an essential impact on pesticide used reduction. Farmers who has access on the ICT tend to use lower pesticide that the farmers who did not use the ICT. The IVQR results, make the claim more robust, which is show a negative and significant impact of ICT on farmers pesticide use in all quartile groups. Therefore, this finding implies that there is a need to develop agriculture related ICT continuously among smallholder farmers to reduce the pesticide use.

Keywords

ICT, pesticide, instrumental variable quantile regression, multiple linear regression, Indonesia.

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Introduction

The intensity of pesticide use has played an important role in increasing agricultural yields and global food security in the past few decades. Ma and Zheng (2021)state that excessive use of chemical pesticides can cause various diseases in humans, such as respiratory disorders, cancer, reproductive disorders, neurological dysfunction, and diabetes. In addition, the intensity of pesticide use will pollute the environment through air, soil, or water. Beketov, Kefford, Schäfer, and Liess (2013) reported that pesticide use can reduce 42% of biodiversity worldwide. Reducing pesticides is an important driver in preserving a healthy and sustainable environment and protecting human health. Various strategies in the form of policy instruments and new technologies are being implemented as a way to reduce the use of agrochemicals. Such strategies include setting maximum limits on pesticide use, increasing farmers' knowledge of the dangers of pesticides, and promoting organic farming practices. Furthermore, the Thai government implemented policies in 2015 such as integrated pest management, pesticide taxes based on the level of agrochemical risk (toxicity), and subsidies for biopesticides as an alternative to reduce the use of chemical pesticides (Grovermann, Schreinemachers, Riwthong, and Berger, 2017). This strategy is seen to be able to reduce almost 35% of the use of chemical pesticides without reducing the average income of farmers. On the other hand, crop insurance programs also have an impact on reducing pesticide use in the agricultural sector. This is in line with the statement of Feng, Han, and Qiu (2021), where crop insurance programs not only stabilize agricultural income but also can significantly reduce the intensity of pesticide use. On the other hand, along with technological advancements, the use of information and communication technology (ICT) also influences farmers' decisions in using pesticides (Ma and Zheng, 2021; Zhao, Pan and Xia, 2021).

Various technologies have been introduced to reduce pesticide use as technology develops.

One of them is information and communications technology (ICT) (Chandio et al., 2023; Manjula et al.; Mwenda et al., 2023; Tambo et al., 2023; Zhu et al.). The advancement of information in agriculture plays a crucial role in effective decision making. The rapid technological advancements and changes in the agricultural system require sophisticated and real-time information and knowledge transfer to farmers through existing media (Rahman, Toiba, Nugroho, Sugiono, and Saeri, 2023). The limited knowledge of farmers in making decisions to adopt new agricultural technology, where the information obtained by farmers about new agricultural technology and practices can only be obtained through agricultural extension services organized by the public, resulting in asymmetry of information. Ali (2012) states that ICT has great potential to transform the agricultural system, including small-scale agriculture, into a profitable farming business. Farmers who consider agriculture as a business will practice diversified cropping systems using ICT-based information to facilitate obtaining the desired information.

The rapid progress of ICT makes information about reforestation and the dangers of excessive use of chemicals easily accessible through reliable applications and websites. In Indonesia, examples of such applications and websites are Simbah, Tanihub, and Pak Tani Digital. According to Zhao et al. (2021), the use of ICT has a significant impact on farmers' ability to obtain information. However, in developing countries, many farmers still rely on traditional information sources (such as information passed down from other farmers), which limits small farmers' ability to obtain market information about agricultural inputs or outputs, leading to low productivity in farming businesses (Hennessy and Wolf, 2018). For example, in the purchase of pesticides, farmers may not know the required dosage, so they fail to make decisions on how much to buy due to inadequate information, resulting in information asymmetry and imperfect competition in the market.

Several studies have investigated the relationship between ICT and pesticide use. Like the study conducted by Zhao et al. (2021), they showed that internet use has a significant direct impact on pesticide reduction. The ability of farmers to obtain information about green (environmentally friendly) production and sales through the internet significantly reduces pesticide use and improves agricultural sustainability. Using data from farmers in China, Hou, Huo, and Yin (2019) state that information technologies such as mobile phones, computers, televisions, and radios have the ability to deliver relevant and timely information. The information facilitates making the right decisions to use resources in the most productive and profitable way. Thus, it affects farmers' decisions in purchasing inputs, including pesticides. The next research by Ma and Zheng (2021)states that the use of smartphones significantly increases pesticide expenditure by 33%. They also added that the use of smartphones affects the expenditure on pesticides and fertilizers heterogeneously, and as a result, the use of smartphones has an impact on pesticide expenditure.

Although research on the relationship between ICT and pesticide use has been extensively studied by several researchers before. However, the findings generated are still inconsistent across the characteristics of farmers. This is because of the differences in socio-demographic conditions of the research locations, such as knowledge, experience, and age. This highlights the importance of examining the impact of ICT on pesticide use in Indonesia, which has not yet been studied. As we know, Indonesia is an agrarian country that certainly has a relatively large use of pesticides. According to data from the Ministry of Agriculture, the number of registered pesticide brands from 2015-2020 has increased to almost 1800 brands, including fungicides, herbicides, and insecticides. Therefore, it is important to understand the role of ICT in pesticide use in Indonesia. The main objective of this research is to determine the impact of ICT on pesticide use in the agricultural sector in Indonesia.

Materials and methods

Research data

The research was conducted in Probolinggo Regency and carried out in October-November 2021. The selection of the location was intentionally done or "purposive" based on specific characteristics considered. The research location will be selected in two villages based on the consideration that most of the population work as potato farmers, namely Wonokerso Village and Ledokombo Village. This research uses a data collection technique conducted by Ma and Abdulai (2017), Rahman et al. (2022) and Rahman, Huang, et al. (2023), which employs multistage sampling. The sampling was conducted in East Java Province by purposively selecting two villages in one district of Probolinggo Regency, namely Wonokerso

Village and Ledokombo Village, based on the consideration that these two villages are potato production centers in Probolinggo Regency. The sample selection was done randomly, with a total of 150 potato farmers selected, 75 respondents from each village. Data collection was conducted using a questionnaire administered through direct interviews with the respondents. The interview gathered information about the use of pesticides, age, education, number of family members, farming experience, asset ownership, land size, farmer group membership, off-farm jobs, ICT, and social networks.

Data analysis

Linear regression analysis aims to analyze the value of the dependent variable if the value of the independent variable is increased or decreased. This analysis is based on the relationship between one dependent variable and one or more independent variables. In this study, multiple linear regression is used because it involves one dependent variable, which is pesticide use (Y), and nine independent variables, which consist of ICT adoption (X_1), Age (X_2), Education (X_3), Number of family members (X_4), Farming experience (X_5), Land area (X_6), Asset ownership (X_7), Farmer group (X_8), and Side job (X_9). The multiple linear regression equation used in this study can be formulated as follows:

$$Y = b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4 + b_5X_5 + b_6X_6 + + b_7X_7 + b_8X_8 + b_9X_9 + e_u \quad (1)$$

Multiple linear regression analysis aims to determine the impact of ICT adoption on pesticide use. However, this Multiple Linear Regression analysis has some limitations. Firstly, the multiple linear regression analysis can only measure the impact of ICT adoption on pesticide use homogeneously, while the impact of ICT adoption on different groups of farmers with different pesticide use may differ. The second limitation of multiple linear regression analysis is that it can only observe observable variables such as age, experience, and others. However, variables that are unobservable cannot be analyzed by multiple linear regression analysis, so to overcome this limitation, further analysis is required (such as IVQR).

To measure the impact of ICT adoption on pesticide use, this study uses Instrumental Variable Quantile Regression (IVQR) analysis. With this analysis, we can estimate and measure the impact of ICT adoption on pesticide use heterogeneously by grouping farmers based on the quantile of pesticide use. According to Ma and Zheng (2021), IVQR can be formulated as follows:

$$y_i = q(\mathbf{g}, \mathbf{x'}, \mathbf{u}) = a_t g + \beta_\tau x' + e \quad (2)$$

where y_i represents the pesticide use of farmers, g is the variable of interest which is the use of ICT measured by a dummy variable (1 if farmers use ICT, and 0 otherwise), x' is the vector of exogenous or control variables (i.e. age, education, number of family members, farming experience, asset ownership, land area, farmer group, and side job), and e is the error term. Furthermore, $q(.)$ is a function of the τ-quantile conditional. a_t and β_τ are the parameters to be estimated at the quantile of Pesticide Use. In addition, in estimating IVQR, at least one instrumental variable is required which is expected to have a significant correlation with the variable of interest (i.e. ICT usage), but does not have a significant effect on the outcome variable (pesticide usage). The instrumental variable in this study will use social network (1 if neighbouring households use smartphones, 0 otherwise).

Results and discussion

Descriptive statistics

The results of the descriptive analysis are presented in Table 1. The variables in this study are divided into three groups, including independent variables, dependent variables, and instrumental variables. Table 1 shows the results of the descriptive analysis.

The first independent variable is ICT (smartphone) using a dummy variable with an average value of 0.58 or 58%, indicating that respondents in this study on average have adopted ICT (smartphone). However, the instrumental variable of neighbour's adoption of ICT (smartphone) is relatively low with an average value of 0.35, indicating that 35% of respondents reported that their neighbours did not adopt ICT (smartphone). The average value of the variable of farmer group is 0.57, indicating that 57% of respondents participated in farmer groups and 43% of farmers did not participate in farmer groups. The average age of respondents is around 48 years old with an average education level of 6 years. This indicates that the respondents only completed elementary school, and the minimum education level of respondents is 0 years, indicating that some respondents did not attend school.

Concept of Variables	Indicator Variable	Scale of Measurement	Mean	Std. Dev
Dependent variable	Pesticide use	Liter	17.47	13.24
	ICT (Smartphone)	Dummy	0.58	0.50
	Age	Year	48.18	12.82
	Education	Year	6.47	3.43
	Number of household members	People	3.89	1.41
Independent Variable	Farming experience	Year	31.39	13.72
	land area	Ha	1.71	1.29
	Asset	Dummy	0.73	0.44
	Farmer group	Dummy	0.57	0.50
	Side jobs	Dummy	0.33	0.47
Instrumental variable	IV	Dummy	0.35	0.48

Source: Primary data processed, 2022

Table 1: Descriptive statistic.

However, some respondents have an education level of around 16 years, indicating that they have completed their education up to a bachelor's degree. The average value of farming experience is 31 years with a minimum average value of 1.43% of the maximum value of 70 years, and a minority (33%) of respondents have a side job outside of farming. In agricultural activities, respondents produce an average of 73% of assets such as diesel, storage facilities, and tractors. The average number of household members for the respondents was 1-4 people per household, with an average land area of around 1.71 hectares. The average pesticide usage was 17.47 litters, with a maximum usage of 50 litters and a minimum of 0.93 litters.

Empirical results

The coefficient of determination is used to see the ability of independent variables to contribute to the dependent variable in a certain percentage. The coefficient of determination analysis is used to determine the overall influence of independent variables on the dependent variable. Chicco, Warrens, and Jurman (2021) explained that Adjusted R squared is the coefficient of determination that has been adjusted for the number of variables and sample size. The results of the R-squared test are presented in the Table 2 below.

Based on Table 2, the Adjusted R-square value is 0.452, which means that the independent variables, namely ICT adoption, age, education, number of family members, farming experience, land area, asset ownership, and farmer groups, collectively explain 45.2% of the variation in pesticide use. This influences the dependent variable by 45.2%, while the remaining 65.8% is influenced by other variables that were not used in this study.

The constant value obtained is 19.578, which means that when the independent variables used in this study are not present, the value of farmers' pesticide use is 19.578 L.

The F-test aims to determine whether the independent variables, consisting of ICT adoption, age, education, number of family members, farming experience, land area, asset ownership, and farmer group membership, have a significant influence on the dependent variable, which is pesticide use. This study obtained a probability value of F equal to 0.000, which indicates that the independent variables have a significant effect on the dependent variable, which is the use of pesticides.

Next, analysis regression testing is used to determine whether each independent variable in the regression model has a significant effect on the dependent variable individually. The analysis results indicate that the variables of ICT adoption, age, land area, farming experience, side jobs, and assets have a significant effect on pesticide use. However, the number of family members, education, and farmer groups do not have a significant effect on pesticide use.

ICT has a negative and significant effect on pesticide use with a significance level of 1% and a coefficient value of -10.880. This means that farmers who use ICT tend to use 10.880 liters less pesticide compared to farmers who do not use ICT. This is because ICT provides various information related to agricultural activities such as the use of inputs, efficient use of pesticides, and the negative impact of pesticide use on the environment and health.This finding is consistent

Variables	Coefficient	Standard Error	Probability
ICT	-10.880	(2.254)	0.000***
Age	0.470	(0.112)	0.000***
Number of household members	0.388	(0.593)	0.514
Education	-0.203	(0.278)	0.468
Total land area	-2.304	(0.725)	0.002***
Farming experience	-0.595	(0.105)	0.000***
Farmer group	1.311	(1.759)	0.457
Side job	-4.920	(2.172)	0.025**
Asset	6.603	(2.302)	0.005***
_cons	19.578	(4.417)	0.000
F count	14.680		
Prob > F	0.000		
Adj R-squared	0.452		

Note: *** Significant 0,01; ** Significant 0,05
Source: Primary data processed, 2022.

Table 2: The impact of ICT adoption on pesticides use: Multiple Linear Regression Analysis.

with the study conducted by Ma and Zheng (2021), which also found that the use of ICT can significantly reduce pesticide use.

Age has a positive and significant effect on pesticide use with a significance level of 1% and a coefficient value of 0.470. This indicates that when a farmer's age increases by one year, pesticide use will increase by 0.470 L. The age factor affects respondents' understanding in accepting new innovations in the use of pesticides. This finding is in line with Jannah and Sunarko (2018), which also found that age significantly affects the use of pesticides. The age factor affects respondents' understanding in accepting new innovations in the use of pesticides. This finding is in line with Jannah and Sunarko (2018), which also found that age significantly affects the use of pesticides.

Experience in farming also has a significant negative effect on pesticide use with a significance level of 1% and a coefficient value of -0.595. This indicates that for each additional year of farming experience, pesticide use is reduced by 0.595 L. Farmers who have more experience in farming provide knowledge about agricultural inputs and pesticide use. This finding is in line with Adesuyi, Longinus, Olatunde, and Chinedu (2018) study which also found that farming experience significantly affects pesticide use. Total land area has a negative and significant effect on pesticide usage with a significance level of 1% and a coefficient value of -2.304, meaning that when a farmer's land area increases by one hectare, pesticide usage will decrease by 2.304 L. The larger the land area owned by farmers; the less pesticide use per hectare tends to be.

The side job has a negative and significant influence on pesticide use with a significance level of 5% and a coefficient value of -4.920. This indicates that farmers who have side jobs tend to use pesticides 4.920 L less than farmers who do not have side jobs. This is because a side job can reduce the intensity of agricultural activities, including the use of pesticides. However, this finding differs from the previous study by Ma, Abdulai, and Ma (2018), which used pesticide expenditures to measure the pesticide variable. Meanwhile, this study used the amount of pesticide used. Assets have a positive and significant effect on pesticide use with a significance level of 1% and a coefficient value of 6.603. It shows that farmers who have assets tend to use 6.603 more pesticides compared to those who do not have assets. This is because farmers who have assets tend to apply higher intensity of agricultural activities, and this can be seen from the use of pesticides.

The measurement of the impact of ICT usage on pesticide use through IVQR analysis is presented in Table 3. The analysis results show that the use of ICT has a negative and significant impact on all quantiles, including the 20^{th}, 40^{th}, 60^{th}, and 80^{th} quantiles. However, the reduction in pesticide use is lower at the lowest quantile (quantile 20 ICT) at 29.795 liters. This is because ICT provides accurate and efficient information on the use of pesticides. Therefore, farmers who adopt ICT tend to use less pesticides compared to those

Variable	Quintile 20		Quantile 40		Quantile 60		Quantile 80	
	Coef.	Standard Error	Coef.	Standard Error	Coef.	Standard Error	Coef.	Standard Error
ICT	-29.796***	(5.882)	-32.692**	(15.253)	-50.086**	(23.471)	-48.584*	(28.797)
Age	0.355**	(0.160)	0.438	(0.327)	0.812***	(0.277)	0.762**	(0.304)
Number of household members	0.634	(0.516)	0.741	(0.526)	0.612	(0.908)	0.599	(0.944)
Education	-0.206	(0.286)	-0.276	(0.382)	-0.637	(0.520)	-0.585	(0.620)
Total land area	-0.423	(1.085)	0.120	(1.241)	1.142	(2.018)	0.998	(2.183)
Farming experience	-0.357**	(0.175)	-0.477	(0.341)	-0.895***	(0.289)	-0.827***	(0.298)
Farmer group	0.948	(1.625)	1.843	(2.332)	-0.996	(4.124)	-0.836	(4.199)
Side job	0.157	(3.762)	-1.234	(4.065)	0.429	(6.046)	2.104	(6.682)
Aset	20.581***	(2.865)	22.122**	(8.956)	32.154**	(15.956)	30.103*	(18.111)
_Cons	4.641	(6.022)	7.933	(8.268)	17.924	(7.322)	49.308	(18.377)

Note: *** Significant <0.01 ** Significant <0.05 * Significant <0.10
Source: Primary data processed, 2022

Table 3: The impact of ICT adoption on Pesticides Use: IVQR.

who do not adopt it. The finding is consistent with a study conducted by Ma and Zheng (2021) on the impact of ICT adoption on pesticide use. They found that the use of ICT can significantly reduce pesticide use.

The study conducted by Zhao et al. (2021) on ICT's ability to help reduce pesticide use found that the use of ICT has a significant impact on reducing pesticide use by farmers. At the 40th quantile, a significant negative result of 32,692 liters was obtained at a significance level of 0.05%. Quantile 60 also obtained a negative and significant result of 23,471 liters with a significance level of 0.05%, while the highest quantile (Quantile 40) obtained a negative and significant result of 48,584 liters with a significance level of 0.10%. This is because the use of ICT provides farmers with quick information on the proper use of pesticides and improves the efficiency of reducing pesticide use, so ICT can contribute to reducing pesticide use. The negative relationship between ICT use and pesticide reduction is also consistent with the findings of (Zhao et al., 2021).

The influence of independent variables such as age, number of household members, education, total land area, farming experience, farmer groups, side jobs, and assets. The research results showed that farming experience has a positive and significant influence on pesticide use in quartile 20, 60, and 80 with a high significance in quantile 60 (farming experience). This indicates that farmers with more experience tend to have more knowledge about inputs and the use of pesticides in agriculture.

Age has a positive and significant influence on pesticide use in quantiles 20, 60, and 80. The highest significance value was at the 60th quantile (age) of 0.812 liters because young age affects farmers' understanding of pesticide use steps. The asset also has a positive and significant effect on pesticide use in all quantiles, namely in quantiles 20, 40, 60, and 80, with the highest significance value in the lowest quantile, namely quantile 20.This concludes that farmers who have assets tend to use higher amounts of pesticides compared to farmers who do not have assets. Here is the table 3 of IVQR analysis results:

Conclusions

This study aims to investigate the impact of ICT usage on pesticide use. The study was conducted in Probolinggo regency, East Java province, using data from 150 respondents from farmer households. This study used instrumental quantile regression (IVQR). The results of the IVQR analysis found that farming experience has a negative and significant impact on pesticide use. However, asset and age have a positive and significant impact. Asset has a significant impact on the 20th quantile, while age has a significant impact on the 60th quantile, meaning that farming experience, asset, and age have an influence on reducing the use of pesticides. The multiple linear regression analysis results obtained show that farming experience, total land area, and side jobs have a negative and significant impact on pesticide use. Meanwhile, age and assets have a positive and significant impact on pesticide use.

The results of IVQR analysis showed that the use of ICT has a negative and significant impact on the 20th, 40th, 60th, and 80th quantiles. However, the highest reduction in pesticide use is in the lowest quantile or the 20th quantile, which amounts to 29.796 liters with a significance of 0.000. The Multiple Linear Regression Test also shows that the use of ICT has a negative and significant impact on pesticide use. This means that the use of ICT has an impact on reducing pesticide use.

Based on the results of the research and data analysis, the study provides several recommendations as follows: For farmers, this study recommends increasing the use of ICT because it can provide information on more efficient use of pesticides. For the government, it is necessary to increase awareness and capability of farmers in using ICT by providing counseling and training through agricultural institutions and cooperatives. Then, the government needs to improve ICT facilities and infrastructure in rural areas by collaborating with internet providers that can provide better internet access.

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