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The Influence of Individual Risk Behavior on Fertilizer Use Decision in Vietnam

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Abstract

Fake or substandard fertilizer is a growing concern in many countries. Even in places not affected by fertilizer quality problems, uncertainty could arise due to doubts about the effectiveness of fertilizer in general. Past literature has examined the impact of risk preferences on fertilizer use intensity. We build upon this literature by showing theoretically and empirically that the marginal effect might not be the same for farmers of different wealth levels. In our study area in northwestern Vietnam, low wealth farmers reduce their fertilizer intensity when their risk aversion increases. The marginal effect for high wealth farmers is insignificant.

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1. Introduction

The overuse of fertilizer is a widespread problem, leading to issues such as biodiversity losses, eutrophication, air pollution, and nitrate leaching which contaminates water resources (He et al., 2007; Kleijn and Sutherland, 2003; Liu et al., 2013; Yadav et al., 1997). Identifying the factors determining the intensity of fertilizer use is a common research focus (Abdoulaye and Sanders, 2005; Alem et al., 2010; Babcock and Hennessy, 1996; Duflo et al., 2011; Lamb, 2003). Due to the uncertainty involved in using this input, examining how risk aversion may affect fertilizer intensity deserves more attention. Uncertainty can arise when low quality fertilizer, which contains fewer nutrients than that labeled on the package, is sold at markets. This creates doubts among consumers about the true nutrient content of fertilizer. This issue is more prevalent in developing countries (Deng, 2012; Hamaguchi, 2011; Kitabu, 2013; Phien, 2013; Zahur, 2010) and is especially problematic for smallholder farmers who do not have the means to test the nutrient content of fertilizer. In regions where trust in fertilizer quality is less of a concern, uncertainty can also occur because farmers may have doubts about the effectiveness of fertilizer in general and about the actual amount needed for their crops. This latter type of uncertainty is not restricted to farmers in countries with fertilizer quality problems and could thus affect farmers throughout the world.

Past literature on risk and fertilizer intensity focuses mainly on the uncertain condition posed by weather variability and soil quality (Babcock, 1992; Isik and Khanna, 2003) or on the impact of external factors, such as insurance or the labor market, on fertilizer use (Babcock and Hennessy, 1996; Lamb, 2003). In an article that examines the link between risk behavior and input use, Roosen and Hennessy (2003) find that risk averse farmers use less fertilizer. In this paper, we theoretically show that this may not be a consistent trend across farmers of all wealth levels. We also test this empirically using household production and risk aversion data collected in Vietnam, a country that is severely affected by fertilizer quality problems. This study is important to understand why there are varying intensities in the application rate among farmers and how risk aversion influences fertilizer intensity, from uncertainty arising from trust issues on the true nutrient content of fertilizer and from doubts about the general effectiveness of fertilizer.

2. Model

In a household production model, let $h(F, X)$ be the production function of fertilizer F and other input X, p be the output price, and q and r be the input prices. Profit is $\pi = ph(F, X) - qF - rX$. We add a term ϵ

to capture the uncertainty pertaining to farmer's belief about the true content or effectiveness of fertilizer. The expected profit is thus $E(\pi) = pE[h(\epsilon F, X)] - qF - rX$ with a variance of $\sigma^2(\pi) = p^2\sigma^2(h)$. We follow Robison and Barry (1987) in analyzing risk behavior using the expected value - variance method, which maximizes the certainty equivalent expression: $\max \pi_{CE} = E(\pi) - \frac{\gamma}{2}\sigma^2(\pi)$. In this case, γ represents the level of risk aversion and has a positive value for a risk averse individual.

Farm households need to produce a minimum amount of output to satisfy household needs, either as food for own consumption or as a product to be sold for cash. This minimum required level depends on the existing wealth of the households. For example, a high wealth household will be able to cover for any potential shortfall in crop output, even without additional farm income, because their stock of wealth acts as an emergency fund for them during bad times. Low wealth farmers do not have the same contingency reserve and thus face a minimum production constraint of $pE[h(\epsilon F, X)] - qF - rX + W_0 \geq \overline{W}$, with W_0 being household wealth and $\overline{W}$ being the minimum wealth needed to satisfy household needs. This minimum amount reflects not only the basic consumption for survival, but can also include other aspects, such as education or more nutritious food, depending on each individual household. The Lagrangian of this analysis is $\mathcal{L} = pE[h(\epsilon F, X)] - qF - rX - \frac{\gamma}{2}p^2\sigma^2(h) + \lambda\{pE[h(\epsilon F, X)] - qF - rX + W_0 - \overline{W}\}$, with λ being the Lagrange multiplier. Assume that F is the input with uncertainty, X is the input without uncertainty, and both inputs are needed to produce the output. The first order conditions are

$$pE(\epsilon h_F) - q - \frac{\gamma}{2}p^2\frac{\partial \sigma^2}{\partial F} + \lambda[pE(\epsilon h_F) - q] = 0, \tag{1}$$

$$pE(h_X) - r + \lambda[pE(h_X) - r] = 0, \tag{2}$$

$$pE(h) - qF - rX + W_0 - \overline{W} \geq 0, \qquad \lambda \geq 0. \tag{3}$$

The arguments of the production function are suppressed to simplify the notation. One of the inequalities in Condition (3) has to hold as an equation due to complementary slackness. For the low wealth farmers, there is a binding minimum production constraint with $pE(h) - qF - rX + W_0 - \overline{W} = 0$. High wealth farmers are not bound by this constraint and thus $\lambda = 0$ for them.

Substituting $\lambda = 0$ into Conditions (1) and (2) and combining them, we derive through implicit function theorem the effect of a marginal change in risk aversion on fertilizer intensity for high wealth farmers:

$$\frac{\partial F}{\partial \gamma} = \frac{p\frac{\partial \sigma^2}{\partial F}}{2E(\epsilon^2 h_{FF}) - 2E(h_{XF}) - \gamma p \frac{\partial^2 \sigma^2}{\partial F^2}}. \tag{4}$$

The direction of the effect depends on whether fertilizer is a risk increasing or risk decreasing input, and on its rate of change. If we assume that fertilizer is risk increasing (Love and Buccola, 1991; Roosen and Hennessy, 2003), then the numerator of Equation (4) is positive. Due to diminishing marginal returns, the denominator is negative if fertilizer risk changes at a non-decreasing rate. In this case, an increase in individual risk aversion would reduce fertilizer intensity. However, if fertilizer risk changes at a decreasing rate, the effect of individual risk aversion on fertilizer intensity becomes ambiguous.

In contrast to the high wealth farmers, the minimum production constraint is binding for the low wealth group. Combining the first order conditions and using the implicit function theorem, the marginal effect of risk aversion on fertilizer intensity for farmers in the low wealth group is

$$\frac{\partial F}{\partial \gamma} = \frac{p\frac{\partial \sigma^2}{\partial F}}{2E(\epsilon^2 h_{FF}) + 2\lambda E(\epsilon^2 h_{FF}) - \gamma p \frac{\partial^2 \sigma^2}{\partial F^2} - E(h_F) + \frac{q}{p}}. \tag{5}$$

An increase in risk aversion also lowers fertilizer intensity among low wealth farmers if fertilizer risk changes at a non-decreasing rate. The effect is ambiguous otherwise. Which of the two wealth groups is more likely to have a negative marginal effect depends mainly on the magnitude of the two terms, $E(\epsilon^2 h_{FF})$ and $E(h_{XF})$. If the expected content and effectiveness of fertilizer or its diminishing marginal return is low, i.e., the magnitude of $E(\epsilon^2 h_{FF})$ is small, then the high wealth group is more likely to have a negative marginal effect of individual risk aversion on fertilizer intensity compared to the low wealth group. A possible reason is that when the expected fertilizer content is low, poor farmers who are risk averse might use more input than the unconstrained optimal level in order to produce enough output for an adequate level of household consumption. In the case of diminishing marginal return of fertilizer, as the low wealth farmers have very limited resources, risk averse low wealth farmers may be more willing to increase fertilizer intensity only if the reduction in the rate of marginal return is small. These two factors lead to an increase in fertilizer intensity when risk aversion rises, which is opposite to the negative marginal effect that risk aversion has on the application intensity of a risk increasing input. Thus, the marginal effect on fertilizer intensity is more likely to be negative for high wealth farmers when the magnitude of the expected fertilizer content and diminishing marginal return of fertilizer is low. If the values of these two factors are high, then it is the low wealth group that is more likely to have a negative marginal effect.

3. Research Area

This study of 294 households is representative of Yen Chau district of Son La province in the mountainous northern uplands of Vietnam. Further details on the sampling methodology are provided in the following section. The research area is in one of the poorest provinces in the country (Minot et al., 2006). Located at an altitude between 281 and 1,088 m.a.s.l., the majority of arable land (77.5%) is used for upland agriculture. Since the beginning of 1990s, the economic growth-driven rise in consumption of high value animal products in Vietnam has increased the demand for maize as an input for livestock and poultry industries (Dao et al., 2002; Thanh and Neefjes, 2005; Minot et al., 2006). Supported by the government's promotion of modern hybrid seeds, maize has consequently become the most profitable cash crop in the northern uplands, with a gross margin superior to that of upland rice and cassava (Wezel et al., 2002a; Thanh and Neefjes, 2005). Our survey data of the 2010 maize growing season find that maize farming in Yen Chau accounts for 70.0% of total arable land and 82.6% of upland land.[1] Maize is also a highly commercialized crop with 94.1% of the harvested output sold. Maize is thus the most important cash crop, accounting for 61.5% of household cash income and 88.9% of household cash crop income.

The use of modern inputs for maize production is widespread in the research area. Hybrid seeds are commonly used, with 85.4% of households growing foreign hybrid maize and 30.7% of households growing local hybrid maize. Only 2.2% of households used non-hybrid maize varieties. All farmers apply chemical fertilizer for maize, with 100% using NPK, 97.5% urea, 13.4% kali, and 0.7% phosphorus fertilizer (Superlan). Fertilizer expenses constitute the most important cash input into maize production, accounting for 71.5% of total cash input costs. Although the expansion of maize has reduced poverty levels in the area, cultivation on sloping upland plots has led to erosion and a decline in soil fertility (Wezel et al., 2002b). Field measurements indicate that the annual soil loss ranges from 21 to 132 Mg/ha in Yen Chau (Tuan et al., 2010). While farmers in the area are very aware of erosion, the adoption rates of soil conservation measures have remained low because farmers are worried about the adverse effects of these measures on maize production through competition for land, labor, sunlight, and nutrients (Wezel et al., 2002b; Saint-Macary et al., 2010). To

[1] Paddy rice, the second most important crop in the research area, accounts for 8.3% of total arable land. Paddy is the predominant crop of the lowlands (52.4% of lowland area) and the major staple crop. Nearly all, 97.4%, of paddy rice harvested in the area is for own consumption. The rest of the arable land is used for upland rice and cassava (5.5%), fruit trees (4.9%), fallow (4.1%), forest tree, bamboo, and teak (2.2%), and other cash crops such as sugarcane, cotton, coffee, and tea (1.4%), vegetables, beans, and tubers (0.9%), and others (2.7%).

combat declining soil fertility, farmers have increased the intensity of fertilizer application to secure yields (Wezel et al., 2002a). While proven to be suitable in the short term, questions arise about the long term financial and ecological sustainability of this approach.

In addition to the increase in fertilizer intensity, poor quality and fake fertilizer has been a growing problem in Vietnam. According to Phien (2013), substandard fertilizer has been found in 45 provinces across the country. These fertilizers contain on average only 70-80% of the labeled content. In the first six months of 2012, there were 1,390 violation cases and 917 tons of fertilizer was seized in Vietnam.

4. Empirical Study

Data were collected in a survey of 294 randomly selected households in May 2011.[2] A two-stage sampling procedure employing the Probability Proportionate to Size (PPS) method was used (Carletto, 1999). In the first stage, 20 villages were randomly selected with PPS method from a village-level sampling frame encompassing all villages of the district. In the second stage, 15 households were randomly chosen in each of the 20 selected villages using updated village-level household list as sampling frames. A team of local enumerators collected the data in structured interviews using carefully tested questionnaires.

We choose to focus our analysis on maize farming since it is the main crop grown in the region and is the largest contributor to cash income. The dependent variable, fertilizer use intensity, is the weight per hectare of all fertilizers applied in maize cropping by each household in 2010. The explanatory variables consist of risk preferences and other control variables that capture household and maize farming characteristics. Since our main interest is the impact of risk aversion on fertilizer intensity, we analyze the effects of risk aversion elicited from two different techniques: a self-assessment question and a lottery game. The self-assessment scale is based on the German Socio-Economic Panel Study conducted by the German Institute for Economic Research (DIW Berlin) and has also been widely used to analyze risk preferences. In the self-assessment methods, subjects are shown a scale with integers ranging from 0 (= fully avoiding risks) to 10 (= fully prepared to take risks) and asked to point to the integer best matching their willingness to take risks. Responses are rescaled so that 0 represents the most risk preferring and 10 the most risk averse. The other risk preference elicitation method is a lottery game, also called the multiple price list technique, based on Holt and Laury (2002). In the lottery game, subjects are given a set of ten choices between two options - a relatively safer option (Option A) and a relatively riskier option (Option B). Each option has two possible

[2]The household survey is part of a panel study that began in 2007 with 300 households being randomly selected. Due to attrition, there were 294 households interviewed in 2011.

payouts with different probabilities of each payout being realized. The payouts in the safer option have a lower variance than those in the riskier option. In the first four choices, the expected value (not shown to subjects) of the safer option is greater than that of the riskier option, whereas in the last six choices the opposite is the case because the probability of the higher payout being realized increased by 10 percentage points in both options with each subsequent choice. Risk preferences are based on the total number of safe options chosen and range from 0 which represents an extreme preference for taking risk to 9 which represents extreme risk aversion. More specifically: 0 total safer option chosen represents extreme risk loving, 1 highly risk loving, 2 very risk loving, 3 risk loving, 4 approximately risk neutral, 5 slightly risk averse, 6 risk averse, 7 very risk averse, 8 highly risk averse, and 9 extremely risk averse. Subjects who selected 10 safer options are excluded from the analysis since this is not a rational selection and it is likely that these subjects did not understand the lottery game. According to expected payouts, approximately risk neutral people will switch to the riskier option in the fifth choice, while risk preferring and risk averse people will switch to the riskier option before and after the fifth choice, respectively. The highest payout amount is equivalent to about four times the average daily per capita expenditures in our sample, 19,854 Vietnamese Dong (VND) or USD 2.60 after adjusting for purchasing power parity (PPP), meaning that potential payouts can be considered substantial. To help subjects understand the ten choices, each choice was explained one at a time along with pie charts and explanations of probabilities via a ten-sided die. After all ten choices had been completed, subjects were shown their selections and given an opportunity to change their responses before one of the ten choices was randomly selected for an actual payout.[3]

As shown in Section 2, the effect of risk attitudes on fertilizer intensity differs between wealth groups. We therefore include an interaction term between risk aversion and household wealth in our regression model. The wealth measure is based on data collected in 2007, to avoid the problem of reverse causality from fertilizer intensity to wealth. The variable is constructed using principal component analysis and follows the methodology by Henry et al. (2003) and Zeller et al. (2006). It is a multi-dimensional index that captures the different aspects of wealth, such as living conditions, assets, and consumption expenditures. Table 1 shows the variables used in constructing the wealth index and their corresponding loading factors.

[Table 1 about here.]

Decision on fertilizer use may also be influenced by other factors, such as natural, human, social, and financial capital (Scoones, 1998), as well as maize production characteristics. We therefore control for these

[3] For more information on the lottery game method, we recommend Nielsen et al. (2013).

components.

Size and quality of the maize cropping land are components of natural capital. The total area of land for maize production represents the size of natural capital. We hypothesize that this area has a negative relationship with the dependent variable because farmers with a smaller maize area have to use their land more intensively to extract more output from the limited land that they have. We also include a variable that reflects soil quality since it can potentially alter the application of fertilizer. Households were asked in a previous round of survey to self-assess the quality of their maize plots on a 3-point-scale (1 = poor soil, 2 = average soil, 3 = good soil). Because households typically produce maize on several plots, these scores are multiplied by the area share of each plot to obtain an indicator of soil quality. We hypothesize that soil quality has a negative relationship with the intensity of fertilizer use because farmers might apply more fertilizer if they think that the soil is poor and needs more nutrients.

We use the literacy dummy of the household head and the share of off-farm income to capture the effect of human capital. Households with literate household heads have better access to information, especially on new technology and inputs, thus could use a greater amount of fertilizer. However, it is also possible that the effect is ambiguous, as the literate household heads may know more about the soil conservation techniques and thus apply less fertilizer. Off-farm income can usually be used as a proxy for financial capital because of its ability to facilitate the purchase of inputs by increasing cash availability. However, a study by Keil et al. (2013) conducted in the same research area indicates that households with higher levels of off-farm income may be labor constrained and have to reduce investment in maize production. We construct a variable that reflects the share of off-farm income in total household cash income from a previous survey in 2007. Households with a large share of off-farm income may have less time to work on the farm and therefore may be less likely to crop as intensively compared to households that generate most of their cash income from agriculture.

To proxy social capital, we include a leadership variable that measures the percentage of household adult members who are leaders in a political or social organization. Such networks strengthen social ties, making it easier for the household to attain resources and information. Similar to the literacy rate, the direction of this effect is ambiguous. To capture the effect of access to markets and infrastructure we include a measurement of the distance in minutes to reach the capital of Yen Chau district, Yen Chau city, by motorbike. We expect a negative relationship with fertilizer intensity due to the greater time and effort needed to go to the market for farmers in more remote areas and the higher costs involved in transporting fertilizers, which is usually carried out by farmers themselves on motorbikes in the study area. In addition to the wealth variable mentioned earlier, the ability to purchase fertilizer depends on its price. In the regression, we include the average price paid for all fertilizer and expect it to have a negative relationship with the intensity of fertilizer use.

Finally, we control for the impact of other maize cropping decisions by including in the regression the degree of specialization in maize production, the breed of maize planted, and the use intensity of other maize inputs. The degree of specialization is represented by the percentage of household cash income from the previous year that comes from maize production. A higher share indicates that the household is more reliant on income from maize farming and is thus expected to have a higher fertilizer use intensity. To account for the type of maize breed, we use the most common local hybrid as the reference category and include the dummy variables of the other three types of maize breeds (foreign hybrid CP, foreign hybrid NK, and a mixture of hybrids). For the intensity of other inputs used in maize production, we include per hectare seed costs, chemical costs, and hired machinery costs. As we do not have data on labor intensity, we include as a proxy the household size per hectare of maize and rice land since these are the two main labor intensive crops in the area. We hypothesize a positive relationship between these variables and fertilizer intensity because a higher level of these inputs indicates a more intensive farming practice and the amount of fertilizer applied per hectare is thus expected to be greater as well. Given this study's focus on maize production, we exclude households that do not farm maize and those with incomplete data. This results in a sample of 250 households. Table 2 provides a summary of these variables.

[Table 2 about here.]

5. Results and Discussion

We examine the determinants of fertilizer use intensity for maize farmers, the output of which can be found in Table 3. As the survey involves cluster sampling at the village level, we run the regressions with robust standard errors.

[Table 3 about here.]

Columns R1 and R2 contain the results with the self-assessment measure and lottery game measure, respectively, of risk aversion. From the control variables, literacy of the household head and the previous share of maize income have a positive effect on fertilizer use intensity. On the other hand, the impact from maize land area, distance to Yen Chau city, and fertilizer price is negative. The results of the maize breed dummies are not included in the table because of space limitations, yet the results (not shown) find that the only statistically significant variable among this group is foreign hybrid CP, indicating that fertilizer intensity increases compared to the local hybrid LVN, which is the reference category. All maize inputs are significant and positive, except for chemicals. This may result from a low use of chemicals among farmers. Pests are not a major problem for maize since it is relatively new in the area, as the main crops used to be upland rice and cassava. In addition, rather than applying herbicide, weeding is usually done by hand. The infrequent use of chemicals can be seen from their low cost per hectare in Table 2.

The main variable of interest for our analysis is risk aversion. We focus on how its impact on fertilizer use intensity varies across different wealth levels. As there is an interaction term of two continuous variables, we calculate the coefficient of risk aversion and its 95% confidence interval across the range of possible wealth index values in our survey sample. We show the results in Figure 1, which includes a histogram depicting the frequency distribution of the wealth index, as suggested by Berry et al. (2012) and Brambor et al. (2006).

[Figure 1 about here.]

We see that at a low level of wealth, the marginal effect of risk aversion on fertilizer use intensity is significant and negative. The value becomes less negative and less significant as the wealth level rises, and becomes insignificant about two-thirds across the graph. The trend of the graph is quite similar for both measures of risk preferences, i.e., the self-assessment scale and the lottery game. The statistically significant part contains between 38% and 43% of all households, with higher wealth households having an insignificant risk aversion coefficient.

We repeat the same analysis with the other part of the interaction term by examining the marginal effect of wealth over the various risk aversion levels of farmers.

[Figure 2 about here.]

The marginal effect of wealth goes from negative to positive as risk aversion increases. However, as shown in Figure 2, the negative coefficient is only statistically significant if we use the self-assessment measure. It is not significant if we use the lottery game measure. At the most risk averse ends of both graphs, the marginal effect of wealth is significant and positive. This corresponds to about 2% and 13%, respectively, of all households. It means that the most risk averse farmers apply fertilizer more intensively as their wealth increases, but the direction of this wealth effect is not clear for farmers who are less risk averse.

The analyses above are performed on the survey sample as a whole. To examine whether the effect of risk aversion is different between the low wealth and high wealth farmers, we split farmers into two groups based on their wealth levels. Thus, instead of the wealth variable, the regression contains a dummy variable that indicates if a household is in the top half of the wealth index.

[Table 4 about here.]

As there is an interaction term involved, we calculate the marginal effect of risk aversion using the regression output from Table 4. The results of the calculation can be found in Table 5, which shows that the marginal effect of risk aversion is insignificant for both the high and low wealth farmers, regardless of the type of risk measurement used.

[Table 5 about here.]

In the next step, we carry out the same analysis of high and low wealth farmers, but instead of dividing the group at the median of the wealth index, we make the cut-offs at different points to examine whether it affects the results. That is, we run the regression with a low wealth group that includes the lowest one-third of the sample in terms of wealth, and the other two-thirds being in the high wealth group. We then increase the size of the low wealth group to two-thirds of the sample and repeat the analysis.

[Table 6 about here.]

Table 6 shows that only for the lowest one-third of wealth among the sample of the low wealth group, does risk aversion have a significant marginal effect on fertilizer intensity. We also extend the analysis to examine farmers in the lowest quarter and lowest tenth of wealth, and the results remain consistent with the marginal effect of risk aversion being negative and significant. When we increase the size of the low wealth group, the marginal effect becomes insignificant. This is similar to the analysis earlier when the group of farmers as a whole was analyzed using the wealth index instead of the wealth group dummy. In both cases, we find that there is a negative marginal effect of risk aversion for low wealth farmers and that the effect is insignificant for high wealth farmers. A possible explanation for this finding is that the risk of fertilizer use changes at a decreasing rate when more fertilizer is applied, that is $\frac{\partial^2 \sigma^2}{\partial F^2} < 0$. According to the Equations (4) and (5) in Section 2, this scenario causes the direction of the marginal effect to be ambiguous instead of negative. In addition, the equations also indicate that the low wealth group is more likely to have a negative marginal effect when the expected content of fertilizer or the magnitude of its diminishing marginal return is high. Based on these characteristics and assuming that fertilizer is risk increasing (Love and Buccola, 1991; Roosen and Hennessy, 2003), we represent Equations (4) and (5) graphically in Figure 3.

[Figure 3 about here.]

From Figure 3, we see that the marginal effect of risk aversion on fertilizer intensity can have different signs depending on the wealth groups of farmers. There is a range within the rate of change of fertilizer risk, $\frac{\partial^2\sigma^2}{\partial F^2}$, in which the direction of the marginal effect is different for the two wealth groups. Within this range, the effect is negative for low wealth farmers and positive for high wealth farmers.

The empirical analysis reflects the difference in the marginal effect of risk aversion between farmers of different wealth levels. The coefficient is negative and statistically significant for farmers in the low wealth group and decreases in its significance across the wealth scale until it becomes insignificant in the higher wealth range. We do not observe the significant and positive marginal effect of risk aversion on fertilizer intensity in the high wealth group. In Section 2, low wealth farmers are defined as those whose wealth is not high enough to offset a crop failure or a huge drop in crop output. This minimum production constraint is not binding for high wealth farmers, as their existing wealth levels are large enough to cover for basic expenses, even if they do not receive any farm income. It is possible that the marginal effect for the high wealth group is not significant in the empirical analysis because the wealth of the farmers in the research area is relatively low and does not reach the level that switches the sign of the marginal effect.

6. Conclusion

This article examines how risk aversion affects the intensity of fertilizer application and shows both theoretically and empirically that the direction of the marginal effect depends on the wealth levels of farmers. Theoretical derivation indicates that the effect has the same direction for farmers of all wealth levels when the rate of change of fertilizer risk is non-decreasing. If the rate is decreasing, there exists a range of the rate that leads to the marginal effect having the opposite signs for the high wealth and low wealth farmers. Which group has a positive or negative effect depends on factors such as the expected content of fertilizer and the magnitude of diminishing marginal return of fertilizer. When these values are high, the low wealth group is more likely to have a negative marginal effect. This seems to be the most plausible scenario in our research area based on the output of the empirical analysis. The results show that the marginal effect of risk aversion is negative and significant among farmers in the low wealth group, and becomes insignificant at the higher end of the wealth index. We do not observe the positive and significant effect for the high wealth farmers, but this could be due to the relative low wealth level overall in the research area. Thus, even at the highest end of wealth in the study area, the wealth level is still not enough to switch the sign of the marginal effect. We do not have data to test whether the expected fertilizer content is actually high.

An interesting topic for future research is to examine the opinion of local residents on the content of their fertilizer and how it affects their fertilizer use decision.

Fertilizer quality is a growing concern in many countries. Other than trying to understand more about the problem and how farmers deal with the situation, it is also important to have policies in place to prevent the doctoring of fertilizer content. Some possibilities include setting up a sector-wide monitoring body and giving special labels to products that meet a certain quality standard. Regular third-party testing of fertilizer sold at markets is also needed, including the testing of products that have already been awarded the special quality labels.

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Table 1. Components of the wealth index and their loading factors in principal component analysis

Description	Mean	Loading factor
Share of children in household	0.33	−0.52
Exterior walls of house are made of bamboo	0.11	−0.48
Type of floor of house is earth	0.15	−0.72
Household receives electricity	0.91	0.72
Household has own connection to electricity	0.83	0.73
Household was classified as poor in 2006	0.22	−0.65
Ln of total current value of buffalo and cattle	12.44	0.55
Ln of total current value of television	11.39	0.82
Ln of total current value of motorbikes	11.63	0.46
Ln of total current value of living room set	7.51	0.59
Ln of total current value of cupboard	10.22	0.77
Daily per capita expenditure (thousand VND[a])	14.81	0.62

Note: [a] VND = Vietnamese Dong, local currency of Vietnam.

Table 2. Descriptions of variables

Description	Mean[a]
Fertilizer use intensity for maize (kg/ha)	1100.22
Land area for maize (ha)	1.32
Self-assessed soil quality for maize cropping area (1 to 3)[b]	1.81
Household head can read and write (1 = yes, 0 = no)	0.84
Percentage of previous household income from off-farm sources	14.17
Percentage of adult household members with a leadership position in an organization	8.37
Distance to Yen Chau city by motorbike (minutes)	42.50
Average fertilizer price paid (thousand VND/kg)[c]	5.17
Percentage of previous household income from maize production	71.39
Household uses local maize hybrid LVN only (1 = yes, 0 = no)	0.15
Household uses foreign maize hybrid CP only (1 = yes, 0 = no)	0.06
Household uses foreign maize hybrid NK only (1 = yes, 0 = no)	0.48
Household uses another maize hybrid or a mixture of hybrids (1 = yes, 0 = no)	0.31
Household size per hectare of maize and rice cropping area	4.46
Seed use intensity (thousand VND/ha)	1543.04
Chemical use intensity (thousand VND/ha)	60.69
Hired machinery intensity (thousand VND/ha)	259.73
Risk aversion based on the self-assessment scale (0 to 10; 10 = extreme risk aversion)	5.12
Risk aversion based on the lottery game (0 to 10; 10 = extreme risk aversion)	6.29

Note: [a] Mean values are calculated from the 250 observations with data in all regression variables.

[b] 1 = poor soil, 2 = average soil, and 3 = good soil.

[c] VND = Vietnamese Dong, local currency of Vietnam.

Table 3. Selected regression outputs for fertilizer use intensity of all maize farmers

Variable	R1	R2
Land area for maize	−154.748**	−131.130*
	(68.864)	(72.897)
Self-assessed soil quality of maize area	65.816	58.578
	(83.614)	(86.145)
Household head literacy	305.387**	225.475**
	(107.793)	(101.254)
Percentage of previous income from off-farm sources	−3.494*	−2.504
	(1.753)	(1.961)
Household adult with leadership position in organization	4.470*	4.362
	(2.467)	(2.964)
Distance to Yen Chau city	−3.333***	−3.322***
	(1.027)	(0.995)
Fertilizer price	−105.150**	−103.306**
	(39.819)	(37.662)
Percentage of previous income from maize production	6.542**	6.725**
	(3.073)	(3.205)
Labor use intensity proxy	72.414*	71.744*
	(40.633)	(40.995)
Seed use intensity	0.201**	0.231**
	(0.089)	(0.086)
Chemical use intensity	0.619	0.682
	(0.428)	(0.444)
Hired machinery intensity	0.222*	0.204*
	(0.112)	(0.101)
Wealth index	−227.562**	−319.276
	(88.469)	(199.187)
Risk aversion (self-assessment)	−32.265*	
	(15.627)	
Risk aversion (lottery games)		−50.399*
		(27.315)
Wealth index × risk aversion	35.752***	50.944**
	(8.617)	(23.767)
Observations	250	250
R-squared	0.435	0.440

Note: Cluster robust standard errors are in parentheses. Asterisk (*), double asterisk (**), and triple asterisk (***) denote significance at 10%, 5%, and 1%, respectively.

Table 4. Selected regression outputs for fertilizer use intensity with maize farmers separated into low wealth and high wealth groups

Variable	R1	R2
Land area for maize	−155.809**	−142.548*
	(70.193)	(77.373)
Self-assessed soil quality of maize area	59.685	54.883
	(83.822)	(85.160)
Household head literacy	278.183**	245.657**
	(116.162)	(102.586)
Percentage of previous income from off-farm sources	−2.778	−2.461
	(1.941)	(2.184)
Household adult with leadership position in organization	4.270*	3.701
	(2.370)	(2.673)
Distance to Yen Chau city	−3.005***	−3.103***
	(0.890)	(0.836)
Fertilizer price	−85.496**	−96.952**
	(31.689)	(36.001)
Percentage of previous income from maize production	7.473**	7.309**
	(3.246)	(3.311)
Labor use intensity proxy	76.294*	75.681*
	(41.574)	(41.506)
Seed use intensity	0.199**	0.235**
	(0.091)	(0.084)
Chemical use intensity	0.591	0.614
	(0.436)	(0.451)
Hired machinery intensity	0.212*	0.206*
	(0.115)	(0.105)
High wealth group dummy	−59.670	−87.044
	(124.635)	(251.315)
Risk aversion (self-assessment)	−39.578	
	(23.740)	
Risk aversion (lottery games)		−59.465
		(41.414)
High wealth group dummy × risk aversion	21.351	24.371
	(19.829)	(36.217)
Observations	250	250
R-squared	0.426	0.431

Note: Cluster robust standard errors are in parentheses. Asterisk (*), double asterisk (**), and triple asterisk (***) denote significance at 10%, 5%, and 1% respectively.

Table 5. Marginal effect of risk aversion for low and high wealth farmers

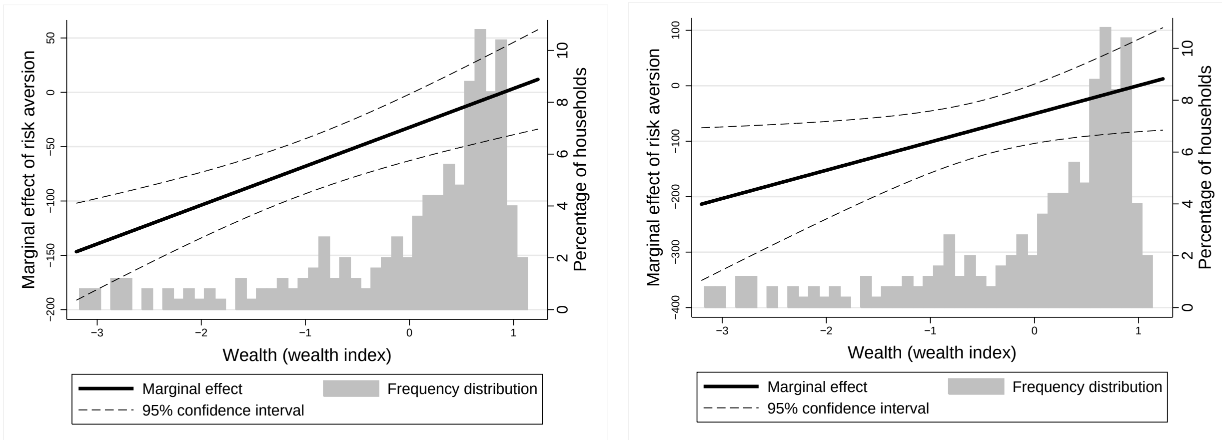
Variable	Wealth category	
	Low	High
Risk aversion (self-assessment)	−39.578 (23.740)	−18.227 (16.266)
Risk aversion (lottery games)	−59.465 (41.414)	−35.094 (30.639)

Note: Cluster robust standard errors are in parentheses.

Table 6. Marginal effect of risk aversion with different sizes of wealth groups

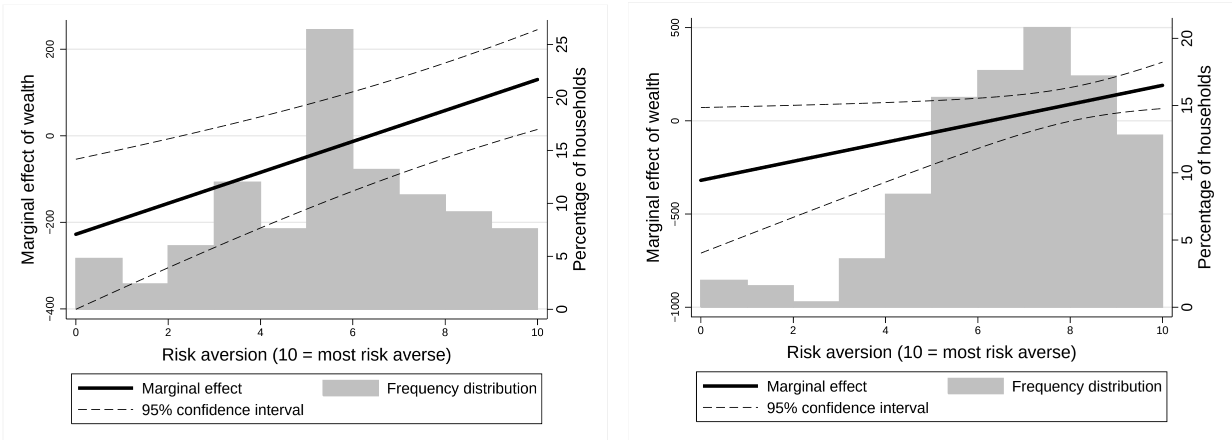
Variable	Wealth category (group size)		Wealth category (marginal effect)	
	Low	High	Low	High
Risk aversion (self-assessment)				
	One-third	Two-thirds	−86.199***	−8.980
			(25.597)	(19.523)
	Half	Half	−39.578	−18.227
			(23.740)	(16.266)
	Two-thirds	One-third	−31.966	−22.489
			(22.832)	(15.765)
Risk aversion (lottery games)				
	One-third	Two-thirds	−118.192**	−13.965
			(48.916)	(27.482)
	Half	Half	−59.465	−35.094
			(41.414)	(30.639)
	Two-thirds	One-third	−57.112	−23.050
			(35.463)	(35.189)

Note: Cluster robust standard errors are in parentheses. Double asterisk (**) and triple asterisk (***) denote significance at 5% and 1%, respectively.



Risk aversion based on self-assessment | Risk aversion based on lottery games

Figure 1. Marginal effect of risk aversion across different wealth levels of farmers.



Risk aversion based on self-assessment

Risk aversion based on lottery games

Figure 2. Marginal effect of wealth across different risk aversion levels of farmers.

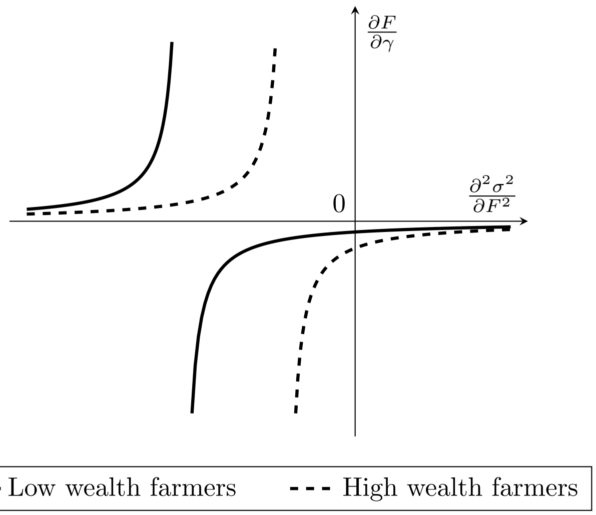


Figure 3. Marginal effect of risk aversion on fertilizer intensity based on a possible scenario from Equations (4) and (5), in which the expected content of fertilizer or the magnitude of its diminishing marginal return is high.