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Impact of risk aversion on fertiliser use: evidence from Vietnam

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ABSTRACT

Fake or substandard fertiliser is a growing concern in many countries. Even in places not affected by fertiliser quality problems, uncertainty could arise due to weather variability, soil quality, or doubts about the effectiveness of fertiliser in general. Past literature has shown that risk aversion leads to lower fertiliser use and farmers become less risk averse as they become wealthier. We build upon this literature by showing that the marginal effect itself might not be the same for farmers of different wealth levels either. In our study, the measures of risk aversion were elicited from two different techniques: a self-assessment question and a lottery game. Results from regression analysis show that the marginal effect of risk aversion on fertiliser use depends on the wealth levels of farmers. Low-wealth farmers reduce their fertiliser intensity when their risk aversion increases. The marginal effect for high-wealth farmers is insignificant.

KEYWORDS

Fertiliser; input use; risk behaviour; uncertainty; wealth

JEL CODES

Q12; O13; D81

1. Introduction

Identifying the factors determining the intensity of fertiliser use has been the focus of numerous studies (Duflo, Kremer, & Robinson, 2011; Lambrecht, Vanlauwe, Merckx, & Maertens, 2014; Takeshima & Nkonya, 2014). Fertiliser is a product that is underused in some countries and overused in others, potentially leading to low production in the former and environmental problems in the latter, such as biodiversity losses, eutrophication, air pollution, and nitrate leaching which contaminates water resources (Ebenstein, 2010; Liu et al., 2013; Yadav, Peterson, & Easter, 1997). Due to the uncertainty involved in using fertiliser, examining how risk aversion may affect its intensity deserves more attention. Uncertainty can arise when low quality fertiliser, which contains fewer nutrients than labelled on the package, is sold in markets. This creates doubts among consumers about the true nutrient content of fertiliser. This issue is more prevalent in developing countries (Deng, 2012; Liverpool-Tasie, Olaniyan, Salau, & Sackey, 2010; Nkana, 2016; Phien, 2013; Zahur, 2010), and is especially problematic for smallholder farmers who do not have the means to test the nutrient content of fertiliser. In regions where trust in fertiliser quality is less of a concern, uncertainty can also occur because farmers may have doubts about the effectiveness of fertiliser in general and about the amount needed for their crops. The latter type of uncertainty is not restricted to farmers in countries with fertiliser quality problems, and could thus affect farmers throughout the world.

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Risk aversion could also affect the intensity of fertiliser use due to uncertain conditions posed by weather variability and soil quality (Babcock, 1992; Dercon & Christiaensen, 2011; Isik & Khanna, 2003). Studies that examine risk behaviour and input use show that risk averse farmers apply less fertiliser (Roosen & Hennessy, 2003), and wealthier farmers are less risk averse (Binswanger, 1981; Chavas & Holt, 1996). In addition to risk behaviour changing with wealth, as shown in previous studies, we find that the marginal impact of risk aversion on fertiliser use may also depend on wealth levels. For low-wealth farmers, an increase of one unit on the risk aversion scale reduces fertiliser application by 30 to 350 kg/ha, depending on the wealth levels and the type of risk measures. This range of reduction is equivalent to 3–32% of the mean fertiliser use intensity in the research area. For high-wealth farmers, an increase in risk aversion has no significant effect on fertiliser use. In this study, the analysis is run using household production and risk aversion data collected in Vietnam, a country that is severely affected by fertiliser quality problems. This research is important for understanding why there are varying intensities in the application rate among farmers and how risk aversion influences fertiliser intensity, which helps in developing policies to change fertiliser use pattern.

The paper proceeds as follows: Section 2 presents the household production model. Section 3 describes the research area, focusing on issues related to fertiliser use in the region. Section 4 explains the empirical study conducted and provides more information on the data collection process and a description of the variables included. Section 5 shows the results of the analysis and discusses the implications thereof. Finally, Section 6 concludes.

2. Conceptual framework

In a household production model, let $h(F, X)$ be the production function of fertiliser 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 fertiliser, where $0 \leq \varepsilon \leq 1$. The lower bound of $\varepsilon = 0$ represents the case in which the farmer thinks that the fertiliser is fake or that the use of fertiliser is completely ineffective. The value of ε is one if the farmer believes that the fertiliser content is as labelled on the package. The expected profit is thus $E(\pi) = pE[h(\varepsilon F, X)] - qF - rX$ with a variance of $\sigma^2(\pi) = p^2\sigma^2(h)$. We follow Robison and Barry (1987) in analysing risk behaviour using the expected value – variance method, which maximises the certainty equivalent expression: $\max \pi_{CE} = E(\pi) - \frac{\gamma(W)}{2}\sigma^2(\pi)$. In this case, $\gamma(W)$ represents the level of risk aversion and it has a positive value for a risk averse individual. Following Binswanger (1981) and Chavas and Holt (1996), risk attitude can vary according to wealth, W.

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 $pE\left[h(\varepsilon F, X)\right] - qF - rX + W_0 \geq \bar{W}$, with W_0 being household wealth and $\bar{W}$ 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 is $\mathcal{L} = pE\left[h(\varepsilon F, X)\right] - qF - rX - \frac{\gamma(W_0)}{2}p^2\sigma^2(h) + \lambda\left\{pE\left[h(\varepsilon F, X)\right] - qF - rX + W_0 - \bar{W}\right\}$ 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

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

$$pE\left(h_X\right) - r + \lambda\left[pE\left(h_X\right) - r\right] = 0, \quad (2)$$

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

The arguments of the risk and production functions 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 $pE(h) - qF - rX + W_0 - \bar{W} = 0$. 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 an implicit function theorem the effect of a marginal change in risk aversion on fertiliser intensity for high-wealth farmers:

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

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

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

An increase in risk aversion also lowers fertiliser intensity among low-wealth farmers if fertiliser 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, $E\left(\varepsilon^2 h_{FF}\right)$ and $E\left(h_{XF}\right)$. If the expected content and effectiveness of fertiliser or its diminishing marginal return is low, i.e. the magnitude of $E\left(\varepsilon^2 h_{FF}\right)$ is small, then the high-wealth group is more likely to have a negative marginal effect of individual risk aversion on fertiliser intensity compared to the low-wealth group. A possible reason is that when the expected fertiliser 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 fertiliser, as the low-wealth farmers have very limited resources, risk averse low-wealth farmers may be more willing to increase fertiliser intensity only if the reduction in the rate of marginal return is small. These two factors lead to an increase in fertiliser 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 fertiliser intensity is more likely to be negative for high-wealth farmers when the magnitude of the expected fertiliser content and diminishing marginal return of fertiliser 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. The research area is in one of the poorest provinces in the country (Minot, Epprecht, Anh, & Trung, 2006). Located at an altitude between 281 and 1088 m above sea level, 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, Vu, Dao, & Coq, 2002; Minot et al., 2006; Thanh & Neefjes, 2005). 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 (Thanh & Neefjes, 2005; Wezel, Luibrand, & Thanh, 2002). Our survey data finds 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 commercialised 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 use non-hybrid maize varieties. All farmers apply chemical fertiliser, and no one uses manure for maize production, with 100% using NPK fertiliser, 97.5% urea, 13.4% kali, and 0.7% phosphorus fertiliser (Superlan). Fertiliser 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, Steinmüller, & Friederichsen, 2002). 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, labour, sunlight, and nutrients (Saint-Macary, Keil, Zeller, Heidhues, & Dung, 2010; Wezel et al., 2002). To combat declining soil fertility, farmers have increased the intensity of fertiliser application to secure yields (Wezel et al., 2002). While proven suitable in the short term, questions arise about the long-term financial and ecological sustainability of this approach.

In addition to the increase in fertiliser intensity, poor quality and fake fertiliser has been a growing problem in Vietnam. According to Phien (2013), substandard fertilisers have been found in 45 provinces across the country. These fertilisers contain on average only 70–80% of the labelled content. In the first six months of 2012, there were 1390 violation cases and 917 tons of fertilisers were 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 was used, employing the Probability Proportionate to Size (PPS) method (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.

4.1. Intensity of fertiliser use

We choose to focus our study on maize farming since it is the main crop grown in the region and is the largest contributor to cash income. The dependent variable of the regression analysis is the weight per hectare of all fertilisers applied in maize cropping by each household in 2010. This is the preferred indicator for capturing fertiliser use intensity as all maize farmers in the region apply fertiliser, and fertiliser weight is the measure that the farmers can recall clearly. For comparison purposes, we also repeat the analysis with three other measures of fertiliser use intensity: urea use intensity, NPK fertiliser use intensity, and the use intensity of the main fertiliser nutrient, nitrogen. As most of the farmers do not know or cannot recall the nutrient composition of the NPK fertiliser that they use, the approximate nitrogen use intensity is calculated from the nitrogen content in urea and the most common grade of NPK fertiliser in northern Vietnam (Shaddick, 2007).

4.2. Risk preference

The explanatory variables consist of risk preference and other control variables that capture household and maize farming characteristics. Nielsen, Keil, and Zeller (2013) compare nine different methods to elicit risk preference of the farmers from the same survey sample. The lottery game method based on Holt and Laury (2002) is the gold standard for risk preference elicitation, as it has the benefits of asking the respondents to make decisions based on real incentives. However, Nielsen et al. (2013) find that the use of a self-assessment scale may be the best alternative to the lottery game method, as it is easier to administer and for the farmers to understand. Therefore, we analyse the effects of risk aversion elicited from two different techniques: a self-assessment scale and a lottery game. Both measures are collected by Nielsen et al. (2013). 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 analyse risk preference. In the self-assessment method, 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). Subjects in the lottery game 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 payouts with different probabilities of each payout being realised (cf. Table 1). 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 realised increases by 10 percentage points in both options with each subsequent choice. Risk preference is 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.[3] 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.

Assuming constant relative risk aversion for payout Y, a farmer's risk preference can be calculated from the following utility function:

$$U(Y) = \frac{Y^{(1-r)}}{1-r}, \quad r \neq 1. \tag{6}$$

Table 1. Choices in the multiple price list.

	Probability of high and low payouts		Payouts in the safer option (Option A) in '000 VND			Payouts in the riskier option (Option B) in '000 VND			
Choice	Low	High	Low	High	*E*(*A*)	Low	High	*E*(*B*)	*E*(*A*)–*E*(*B*)
1	0.90	0.10	33.0	41.0	33.8	2.0	79.0	9.7	24.1
2	0.80	0.20	33.0	41.0	34.6	2.0	79.0	17.4	17.2
3	0.70	0.30	33.0	41.0	35.4	2.0	79.0	25.1	10.3
4	0.60	0.40	33.0	41.0	36.2	2.0	79.0	32.8	3.4
5	0.50	0.50	33.0	41.0	37.0	2.0	79.0	40.5	−3.5
6	0.40	0.60	33.0	41.0	37.8	2.0	79.0	48.2	−10.4
7	0.30	0.70	33.0	41.0	38.6	2.0	79.0	55.9	−17.3
8	0.20	0.80	33.0	41.0	39.4	2.0	79.0	63.6	−24.2
9	0.10	0.90	33.0	41.0	40.2	2.0	79.0	71.3	−31.1
10	0.00	1.00	33.0	41.0	41.0	2.0	79.0	79.0	−38.0

Notes: The conversion rate in 2011 for the local currency, Vietnamese Dong (VND), after adjusting for purchasing power parity (PPP) is 7625 VND/1 USD (The World Bank, 2014).

The highest payout amount is equivalent to about four times the average daily per-capita expenditure 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 were 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. The descriptive results in Table 3 indicate that according to the self-assessment scale, on average, farmers are slightly risk averse with a mean of 5.12. This finding is confirmed by risk preference elicited in the lottery game. In the lottery game, respondents chose on average 6.28 safer options, indicating that respondents are on average risk averse.

4.3. Wealth

In order to test whether the effect of risk attitude on fertiliser intensity differs between wealth groups, we 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 fertiliser intensity to wealth. The variable is constructed using principal component analysis (PCA) and follows the methodology by Henry, Sharma, Lapenu, and Zeller (2003) and Zeller, Sharma, Henry, and Lapenu (2006). We use this method because it produces a multi-dimensional index that captures the different aspects of wealth, such as living conditions and total current value of assets. The choice of individual variables that reflect the relative poverty of the region allows us to focus more on the low-income households in the region by generating an index that has a wider spread at the lower end of the range, as opposed to the distribution of household income and household expenditure (cf. Figure 1).

For comparison purposes, we also repeat the analysis using household income and household expenditure to represent wealth, in order to examine any potential differences in the results. As the data-set does not contain information on total household income, we calculate it using the data from the two questions on maize income and its percentage in total income. Household expenditure includes all non-farm expenditure.

We follow the procedures recommended by Henry et al. (2003) in filtering the indicators for the wealth index. The first step is to collect the potential variables that could be included in the different categories of wealth. We then run PCA on the variables and keep only the ones with a component loading higher than a pre-determined baseline, which, based on the recommendation by Henry et al., is 0.30 in absolute value. Following this filtration, there are nine variables remaining. We list these variables in Table 2 together with their respective loading factors.

We examine the validity of our final list of wealth indicators by checking whether it fulfils the following two criteria: its eigenvalue should be higher than one and the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy has to be more than 0.60. Low KMO scores indicate that the variables have too little in common and the model is not appropriate. A score of 0.60 is considered mediocre,

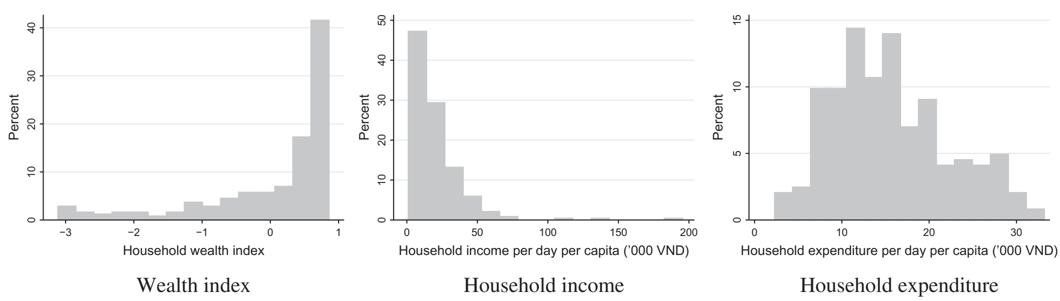


Figure 1. Frequency distribution of farmers' wealth based on three different measures of wealth.

Table 2. Final list of indicators in the wealth index.

Description	Mean	Loading
House exterior wall is made of bamboo (1 = yes, 0 = no)	0.11	−0.4896
House floor is earth with no covering (1 = yes, 0 = no)	0.15	−0.7169
Household has electricity (1 = yes, 0 = no)	0.91	0.7612
Household has own connection to electrical grid (1 = yes, 0 = no)	0.83	0.7820
Log(Total current value of cattle)	12.44	0.5681
Log(Total current value of television)	11.39	0.8505
Log(Total current value of motorcycle)	11.63	0.4126
Log(Total current value of living room furniture)	7.51	0.5841
Log(Total current value of cupboard)	10.22	0.7726

Table 3. Description of variables.

Description	Mean	Standard deviation
Total fertiliser use intensity for maize (kg/ha)	1102.25	858.10
Urea use intensity for maize (kg/ha)	320.14	314.13
NPK fertiliser use intensity for maize (kg/ha)	767.39	598.14
Nitrogen use intensity for maize (kg/ha)	185.63	167.12
Total farm area (ha)	1.72	0.96
Lagged self-assessed soil quality for maize cropping area[a]	1.81	0.48
Household head can read and write (1 = yes, 0 = no)	0.83	0.37
Number of adults above 15 year-old per hectare of farm area	2.51	2.22
Percentage of lagged household income from off-farm sources	14.94	24.16
Gender of household head (1 = male, 0 = female)	0.91	0.28
Percentage of adult members with a leadership position in an organisation	8.16	18.18
Distance to Yen Chau city by motorcycle (minutes)	42.65	34.63
Household received any extension visits in past two years (1 = yes, 0 = no)	0.26	0.44
Self-assessed ease of access to agricultural extension[b]	3.09	1.06
Average fertiliser price paid ('000 VND/kg)	5.18	0.82
Percentage of lagged household income from maize production	72.58	26.88
Household uses local maize hybrid LVN only (1 = yes, 0 = no)	0.13	0.34
Household uses foreign maize hybrid CP only (1 = yes, 0 = no)	0.06	0.24
Household uses foreign maize hybrid NK only (1 = yes, 0 = no)	0.48	0.50
Household uses another or a mixture of hybrids (1 = yes, 0 = no)	0.33	0.47
Seed cost ('000 VND/ha)	1546.83	663.40
Agrochemical cost[c] ('000 VND/ha)	61.84	200.08
Hired machinery cost ('000 VND/ha)	266.12	527.79
Lagged maize yield ('000 kg/ha)	7.38	4.79
Lagged maize output price ('000 VND/kg)	3.62	0.69
Risk aversion based on the self-assessment scale[d]	5.14	2.36
Risk aversion based on the lottery game[e]	6.30	1.97

Note: Summary statistics are calculated from the 243 observations in the main regression analysis.
[a]Score from 1 to 3, with 1 = poor soil, 2 = average soil, and 3 = good soil.
[b]Score from 1 to 5, with 1 = very bad and 5 = very good.
[c]Includes pesticide, herbicide, and fungicide.
[d]0 represents extreme willingness to take risks and 10 represents extreme risk aversion.
[e]Based on the total number of safer options chosen in the lottery game, ranging from 0 to 9.

0.70 is middling, 0.80 is good, and 0.90 is excellent (Kaiser, 1974). The eigenvalue for our index is 4.10 and it has a KMO measure of 0.84.

4.4. Control variables

Decision on rural livelihood strategies, such as agricultural intensification, may also be influenced by other factors (Scoones, 1998):

$$L = g(N, H, S, F), \tag{7}$$

with N being natural capital, H being human capital, S being social capital, and F being financial capital. We therefore control for these components, as well as maize production characteristics. Table 3 provides a summary of these variables. Size and quality of the cropping land are components of natural capital. Minten, Koru, and Stifel (2013), Teshome, de Graaff, and Kessler (2016), and Zerfu and Larson (2010) show that total farm area has a negative relationship with fertiliser use intensity after controlling for wealth. A possible reason is that farmers with a smaller 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 fertiliser (Lambrecht et al., 2014; Minten et al., 2013; Sinyolo, Mudhara, & Wale, 2016). 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). As 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 hypothesise that soil quality has a negative relationship with the intensity of fertiliser use because farmers might apply more fertiliser if they think that the soil is poor and needs more nutrients.

We use the literacy dummy of the household head and the number of household adults above 15 year-old to capture the effect of human capital and labour availability (Ade Freeman & Omiti, 2003; Lambrecht et al., 2014). We include also the gender of household head in the regression (Marenya & Barrett, 2009; Minten et al., 2013; Yagura, 2009).

Households with literate household heads have better access to information, especially on new technology and inputs, and thus could use a greater amount of fertiliser (Marenya & Barrett, 2009; Zerfu & Larson, 2010). 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 fertiliser. A higher labour availability is expected to increase the rate of fertiliser application. Lambrecht et al. (2014) show that 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, Saint-Macary, and Zeller (2013), conducted in Vietnam, indicates that households with higher levels of off-farm income may be labour 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 round of the survey. 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 (Yagura, 2009).

As a proxy for social capital, we include a leadership variable that measures the percentage of household adult members who are leaders in a political or social organisation. Such networks strengthen social ties, making it easier for the household to acquire resources and information (Kormawa, Munyemana, & Soule, 2003; Lambrecht et al., 2014; Sinyolo et al., 2016; Zerfu & Larson, 2010). 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 motorcycle. We expect distance to have a negative relationship with fertiliser 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 fertiliser (Lambrecht et al., 2014; Marenya & Barrett, 2009; Minten et al., 2013), which is usually carried out by farmers themselves on motorcycles in the study area. As low levels of fertiliser use could be caused by lower wealth or less information about best-practice application of fertiliser, we include in the regression the self-assessed ease of access to agricultural extension and a dummy variable on whether the household received any extension visits in the past two years as control variables (Kormawa et al., 2003; Marenya & Barrett, 2009), in order to reduce the confounding effect between wealth and information. In addition to wealth, the ability to purchase fertiliser depends on the input price. Therefore, we include in the regression the average price paid for all fertilisers. Sheahan, Ariga, and Jayne (2016), Sinyolo et al. (2016), and Zerfu and Larson (2010) show that fertiliser price has a negative relationship with its use intensity.

We control for the impact of other maize cropping decisions by including: a variable on the degree of specialisation in maize production (Ade Freeman & Omiti, 2003; Kormawa et al., 2003); the breed of maize planted (Marenya & Barrett, 2009); the costs of other maize inputs (Kormawa et al., 2003;

Marenya & Barrett, 2009); and the yield and output price of maize from the past year (Sheahan et al., 2016; Zerfu & Larson, 2010). The degree of specialisation is represented by the percentage of household cash income from the previous year that comes from maize production. Ade Freeman and Omiti (2003) and Kormawa et al. (2003) find that farmers who focus more on cash crops or who have greater market orientations tend to apply more fertiliser. As maize is the main cash crop in the research area, a higher income share from maize production indicates that the household is more reliant on income from maize farming and is thus expected to have a higher fertiliser 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 costs of other inputs used in maize production, we include seed cost, agrochemical cost, and hired machinery cost. We hypothesise a positive relationship between these variables and fertiliser intensity because higher costs of other inputs could indicate the farmers also use more fertiliser. Finally, higher yield and output price of maize from the past year are expected to increase the incentive of applying more fertiliser.

Given this study's focus on maize production, we exclude households that do not farm maize and those whose data on risk preference or household income are not available. This results in a sample of 243 households for the regression using the wealth index, 235 households for the regression using household income, and 243 households for the regression using household expenditure. In order to check for potential biases caused by the exclusion of some households in the regression, we use a two-sample t-test to compare the means of the included and excluded groups in all four measures of fertiliser intensity, three measures of wealth, and two measures of risk preference, respectively. This is conducted on the included and excluded groups in the regression with wealth index, on those in the regression with household income, and then on those in the regression with household expenditure. We also compare the means of all these variables among the maize and non-maize growing farmers. Test results show that the differences are not statistically significant at the 10% level in all cases.

5. Results and discussion

We examine the determinants of fertiliser use intensity for maize farmers, the output of which can be found in Table 4. We begin by running the analysis using OLS without the interaction term between wealth and risk preference,

$$F_i = \beta_0 + \boldsymbol{\beta_1 X_i} + \beta_2 w_i + \beta_3 r_i + \epsilon_i, \tag{8}$$

with F_i being fertiliser use intensity, w_i being wealth, r_i being risk preference, and $\boldsymbol{X_i}$ being a list of control variables mentioned in Section 4. We then repeat the analysis with the interaction term included,

$$F_i = \beta_0 + \boldsymbol{\beta_1 X_i} + \beta_2 w_i + \beta_3 r_i + \beta_4 (w_i \times r_i) + \epsilon_i. \tag{9}$$

In order to check for the robustness of the results and the potential variations due to the different ways of capturing fertiliser use intensity and wealth, we repeat the regression analysis with four different measures of fertiliser intensity: weight per hectare of all fertilisers, weight per hectare of urea, weight per hectare of NPK fertiliser, and weight per hectare of nitrogen in all fertilisers. We further use three separate indicators of wealth: household income, household expenditure, and a multi-dimensional wealth index constructed from living conditions and current value of assets.

As the survey involves cluster sampling at the village level, we run the regressions with cluster robust standard errors. Columns R1 and R2 contain the results with the self-assessment measure of risk aversion and columns R3 and R4 contain the results with the lottery game measure. An interaction term of risk aversion and wealth is added into regressions R2 and R4. From the control variables, literacy of the household head and labour availability have a positive effect on fertiliser use intensity. On the other hand, the impact from total farm area, lagged off-farm income share, distance to Yen Chau city, and fertiliser price is negative. Lagged output price of maize from the previous year has a positive effect on fertiliser use. Seed cost is significant and positive, but not the other input costs. This may result from the low use of hired machinery and agrochemical among farmers. Pests are not a major

Table 4. Selected regression outputs for fertiliser use intensity of all maize farmers.

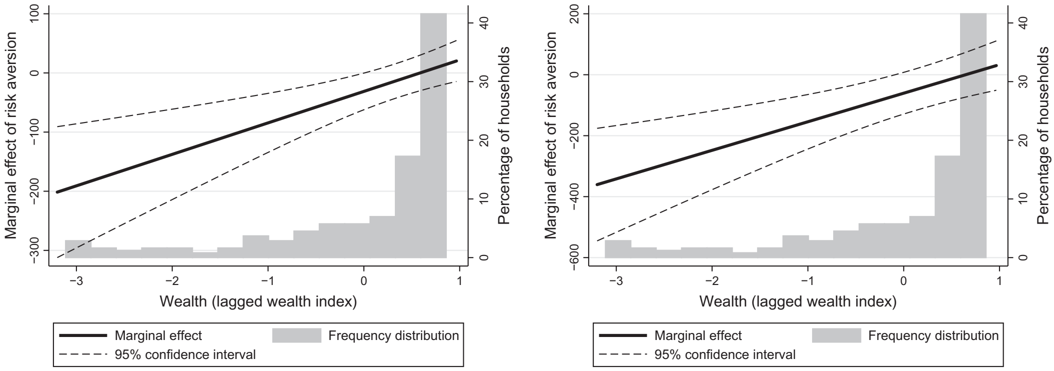
Variable	R1	R2	R3	R4
Total farm area	−116.081***	−110.848***	−109.699**	−93.864**
	(33.311)	(38.528)	(38.400)	(42.781)
Household head literacy	333.592**	344.722**	291.875**	179.799*
	(129.893)	(123.671)	(119.766)	(102.340)
Labour availability proxy	70.740***	75.560***	71.972***	68.207***
	(12.481)	(12.228)	(15.318)	(18.222)
Lagged income % from off-farm	−4.139*	−4.185*	−4.266*	−4.452*
	(2.241)	(2.150)	(2.270)	(2.376)
Gender of household head	5.537	−20.053	46.943	129.369
	(157.081)	(157.618)	(147.811)	(172.838)
Distance to Yen Chau city	−2.902***	−2.453***	−2.865***	−2.667**
	(0.833)	(0.793)	(0.801)	(1.007)
Extension visits in past two years	−6.939	0.886	19.483	−16.161
	(115.037)	(119.226)	(103.749)	(93.986)
Fertiliser price	−106.276**	−111.996*	−110.667**	−107.633**
	(45.592)	(54.747)	(49.098)	(50.552)
Lagged income % from maize	3.527	3.012	3.138	2.190
	(2.348)	(2.302)	(2.342)	(2.137)
Seed cost	0.211**	0.214**	0.250***	0.246***
	(0.096)	(0.094)	(0.080)	(0.076)
Agrochemical cost	0.704	0.753	0.724	0.865
	(0.609)	(0.604)	(0.629)	(0.624)
Hired machinery cost	0.186	0.196	0.181	0.179
	(0.156)	(0.154)	(0.143)	(0.134)
Lagged maize yield	6.134	8.149	6.305	11.156
	(9.769)	(8.349)	(9.908)	(9.353)
Lagged maize output price	177.916***	194.059***	155.550***	143.362**
	(43.150)	(42.881)	(49.791)	(56.215)
Lagged wealth index	−46.599	−335.850**	−30.547	−602.360**
	(79.720)	(151.292)	(77.430)	(221.662)
Risk aversion (self-assessment)	−27.611	−31.232*		
	(21.270)	(15.807)		
Risk aversion (lottery games)			−48.902	−60.595*
			(43.821)	(34.917)
Lagged wealth index × risk aversion		53.205***		93.734***
		(15.357)		(26.373)
Observations	243	243	243	243
R^2	0.320	0.341	0.326	0.361

Notes: Village level cluster robust standard errors are in parentheses. Due to space limitations, we do not show the results of the maize breed, soil quality, extension access, and leadership position variables, which are all statistically insignificant. The results of these variables are available upon request.
*Significance at 10%; **Significance at 5%; ***Significance at 1%.

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 these chemicals can be seen from their low costs per hectare in Table 3.

The main variable of interest for our analysis is risk aversion. We focus on how its impact on fertiliser use intensity varies across different wealth levels. As there is an interaction term of two continuous variables in regressions R2 and R4, 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 2, which includes a histogram depicting the frequency distribution of the wealth index, as suggested by Berry, Golder, and Milton (2012) and Brambor, Clark, and Golder (2006).

We see that at the lower level of wealth, the marginal effect of risk aversion on fertiliser 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 the same for both measures of risk aversion, i.e. the self-assessment scale and the lottery games. The statistically significant part contains 32% of all households in the regression. For these farmers, an increase of one unit on the risk aversion scale reduces fertiliser application by 30 to 200 kg/ha, based on the self-assessed risk aversion scale, and by 70 to 350 kg/ha, based on the lottery game risk aversion



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

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

scale. This value depends on the wealth level of each household and the range of reduction between 30 and 350 kg/ha is equivalent to 3–32% of the mean fertiliser use intensity in the research area. The coefficients of both measures of risk aversion are insignificant for the farmers with higher wealth. As the number of clusters is small in estimating the robust standard errors, we follow the suggestion of Angrist and Pischke (2009, Chapter 8) and rerun the analysis using the maximum of conventional and robust standard errors. The main results are consistent and show that the marginal effect of risk aversion on fertiliser use is negative and significant for the low-wealth farmers, containing 30% of all households in the regression. The coefficient at the higher wealth level remains insignificant.

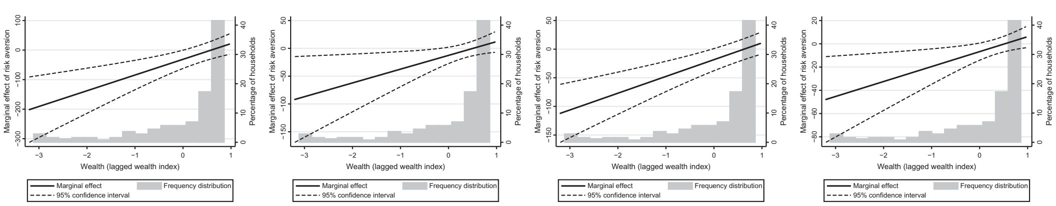
5.1. Other measures of fertiliser use intensity

As there are alternative ways of measuring the intensity of fertiliser use, we rerun the regression using these different measures. Figure 3 shows the coefficient of risk aversion and its 95% confidence interval with the four different measures of fertiliser use intensity.

Although there is a difference in the width of the 95% confidence interval, the trend of the coefficient remains the same, regardless of which measure of fertiliser intensity is used. Risk aversion has a negative and statistically significant effect on fertiliser use for the poorest one-third of farmers. The effect is insignificant for the farmers with higher wealth.

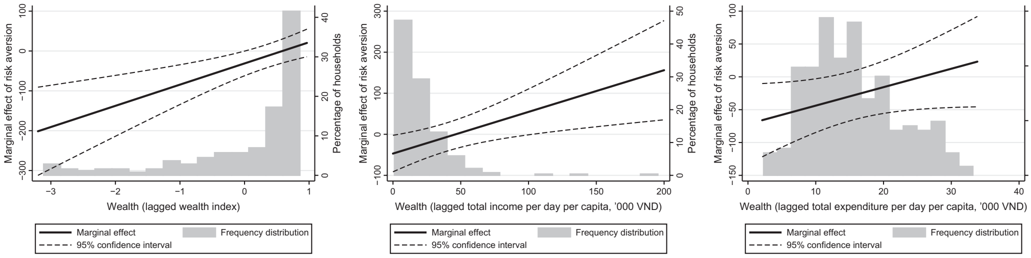
5.2. Other measures of wealth

In the analysis above, we use a wealth index to represent household wealth because the index is multi-dimensional and captures the different aspects of wealth. We also examine the potential changes in outcome if we chose a different type of wealth indicator. In this case, we use the lagged household per-capita income and the lagged household per-capita expenditure, which are both more liquid indicators of wealth in comparison to the asset-based wealth index (Figure 4).



All fertiliser types | Urea | NPK fertiliser | Nitrogen content

Figure 3. Marginal effect of risk aversion across different wealth levels of farmers using various measures of fertiliser use intensity.



Wealth index Household income Household expenditure

Figure 4. Marginal effect of risk aversion across different wealth levels of farmers using various measures of wealth.

The results show that even though there is a reduction in the statistically significant section when household income is used (9% of all households, compared to 32% and 35%, respectively, when wealth index and household expenditure are used), the trend remains consistent. Risk aversion has a negative effect on fertiliser use for farm households with the lowest wealth, regardless of whether household wealth is represented by wealth index, household income, or household expenditure. The effect becomes insignificant as wealth increases.

6. Conclusions

This article examines how risk aversion affects the intensity of fertiliser application and shows that the direction of the marginal effect depends on the wealth levels of farmers. It is negative and significant among farmers with the lowest wealth, and becomes insignificant at the higher end of the wealth indicator. Fertiliser quality is a growing concern in many countries. Risk aversion could lead to lower fertiliser use among low-wealth farmers. We compare the recommended level of nitrogen application in the research area (Tuan et al., 2014) with the approximate nitrogen use intensity of each household, calculated from the nitrogen content in urea and the most common grade of NPK fertiliser in northern Vietnam (Shaddick, 2007). Among the households who underuse nitrogen fertiliser, those from the poorest tercile apply significantly less of the input than the farmers with higher wealth. Uncertainty in fertiliser quality could worsen the situation because, as shown in the analysis, risk aversion lowers fertiliser use among the low-wealth farmers. Thus, in addition to 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 fertiliser content. Some possibilities include setting up a sector-wide monitoring body (Saenger, Torero, & Qaim, 2014) and giving special labels to products that meet a certain quality standard. Regular third-party testing of fertiliser sold at markets is also needed, including the testing of products that have already been awarded the special quality labels.

Notes

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%).
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.
3. 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.

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