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Inadequate N Application of Rice Farmers in the Philippines: Problems, Causes, Solutions
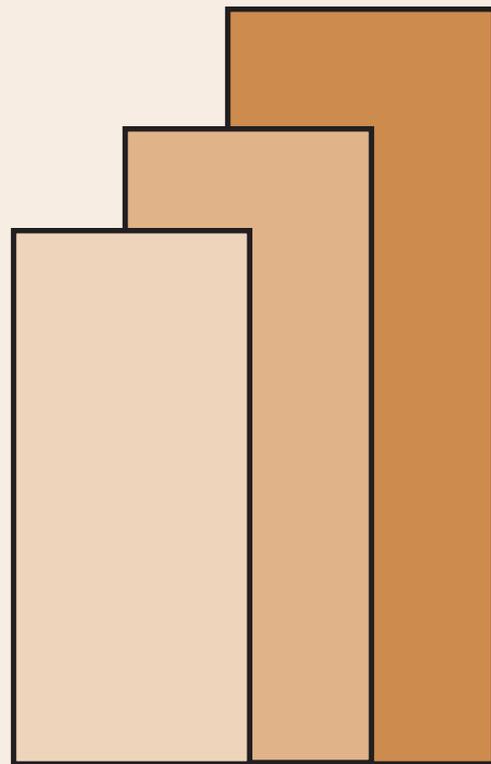
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Inadequate N Application of Rice Farmers in the Philippines: Problems, Causes, Solutions

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ABSTRACT

Inadequate application of nitrogen (N) fertilizer has been identified by the Food Staples Suffiency Program (FSSP) as a major constraint in achieving rice self-sufficiency. The available literature on fertilizer application in the Philippines tends to find inadequate N application under the agronomic and economic criteria. Explanations for the gap may be grouped under the following sets of factors: external constraints; attitude towards risk; and internal constraints. Different explanations imply different policy solutions, hence it is critical to correctly identify the most relevant explanations. A new estimation using FAO Fertibase data confirms the finding of inadequate N application by rice farmers in the Philippines. Additional study is proposed covering the following: a) comparing actual to optimal N application using secondary data for Central Luzon (obtained from the International Rice Research Institute); b) identifying the reasons for inadequate N application using primary data collected from a survey of rice farmers in Nueva Ecija.

Keywords: efficiency, fertilizer, yield gap, risk aversion, prospect theory, behavioral economics

1. Introduction

Production of rice, the country's main staple, has recorded major successes in recent years; by 2014, palay yield breached the 4-ton benchmark. Nonetheless, the goal of rice self-sufficiency remains elusive. Yields in the country remain lower than those attained by major rice producers Indonesia, Vietnam, and China. Fertilizer application in the Philippines is likewise lower than those of the major rice producers. Insufficient fertilizer application has been highlighted as a constraint to attaining rice self-sufficiency, according the Food Staples Sufficiency Program or FSSP (DA National Rice Program, 2012). An increase in yield of just one ton per ha in 2013 would have resulted in a milled rice production of14.3 million tons, 21% higher than the official consumption estimate of 11.8 million tons.

Among the soil macro-nutrients, the biggest constraint is nitrogen; at the target yield of 5 tons/ha, the recommended application rate for nitrogen is 100 kg/ha; in fact, in 2009, the application rate for irrigated farms in dry and wet seasons was 74 and 73 kg/ha, respectively; for rainfed farms the application rate was 39 and 57 kg/ha, respectively. Constraints to increasing fertilizer application rates include "high fertilizer price" and "lack of water" (DA National Rice Program, 2012).

Based on past research by Schultz (1964) and others, farmers are deemed "rational but poor", hence the persistent failure to apply the right amount of nitrogen fertilizer is puzzling. This study explores the nature of the problem of inadequate N application, its possible explanations, and possible solutions to the problem, with accompanying implications for policy. The rest of the paper is organized as follows: background of the problem and related literature on the problem of inadequate N application is reviewed in Section 2. Section 3 presents a test of the hypothesis of inadequate N application using FAO Fertibase data for the Philippines. Lastly, Section 4 presents a proposal for conducting further research on ascertaining and explaining inadequate N application.

2. Background and related literature

2.1. Palay production trends

In the Philippines, palay is the largest sub-sector in agriculture, accounting for one-fourth of agricultural gross value added. Palay production since 1994 has been rising, peaking at at 19 million tons in 2014 (Figure 1). It also hit a peak yield of 4.0 tons per ha, up from 2.9 tons per ha twenty years earlier.

Figure 1: Output (million tons) and yield (tons/ha) of palay, Philippines, 1994 - 2014
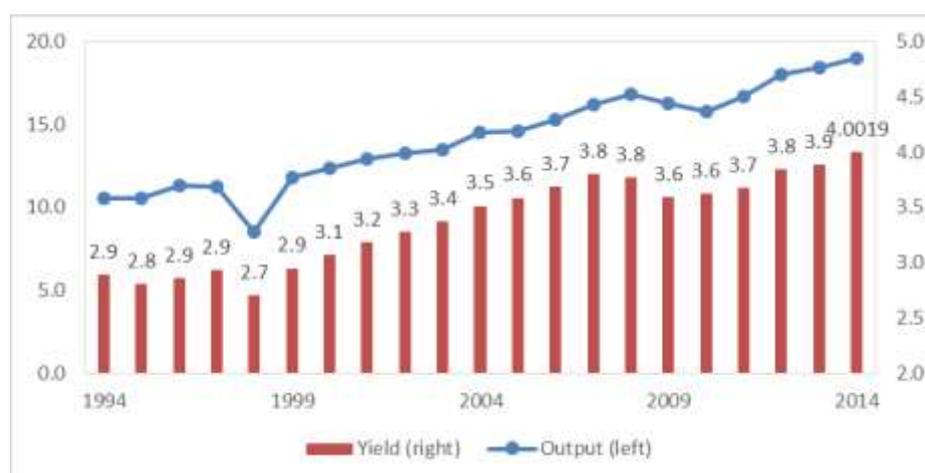
Source: PSA-BAS.

Despite these impressive gains, palay yield in the Philippines far below those of large rice producers in East and Southeast Asia, namely China, Vietnam, and Indonesia (Figure 2). Yield is 1.6 tons per ha below that of Vietnam, a major rice exporting country, and even 1.2 tons/ha below that of Indonesia, a major rice importing country.

Figure 2: Paddy rice yield, tons/ha, selected Asian countries, 2013
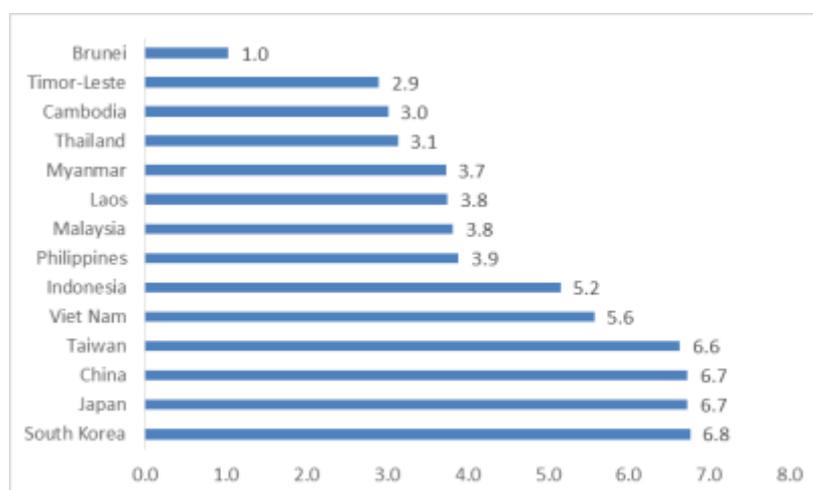
Source: FAOStat.

Yield is a function of inputs, hence yield differences across countries may be explained in part by differences in input intensity; in particular, in the application rate for chemical fertilizer (Figure 3). Palay is the biggest user of fertilizer, hence overall fertilizer use is determined by fertilizer application by the rice sector. Since 2002 the application rate of the Philippines has been lower than that of China and Vietnam, and even that of Indonesia (since

2005) and Thailand (since 2010). In the Philippines the predominant type of fertilizer is nitrogen (Figure 4). Nitrogen fertilizers (mostly urea) account for 62 – 71 percent of applied fertilizer by volume.

Figure 3: Fertilizer application rates, kg/ha, selected Asian countries, 2002 - 2012
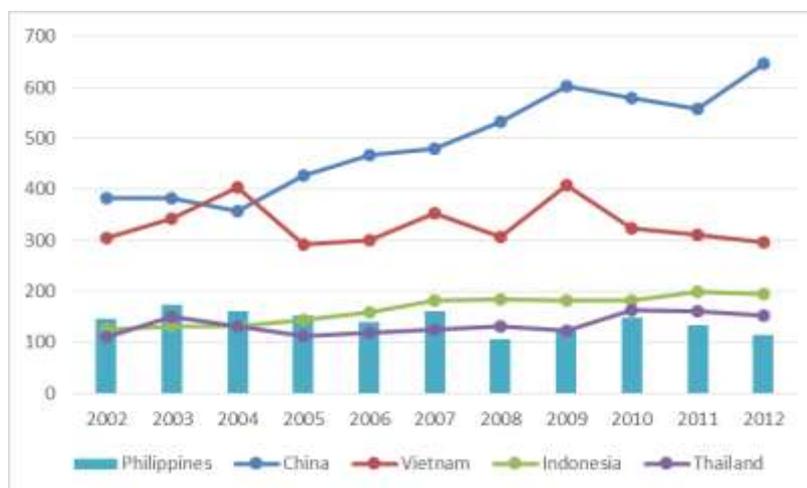
Source: World Development Indicators (data.worldbank.org)

Figure 4: Fertilizer application by type, kg/ha, Philippines, 2002 - 2011
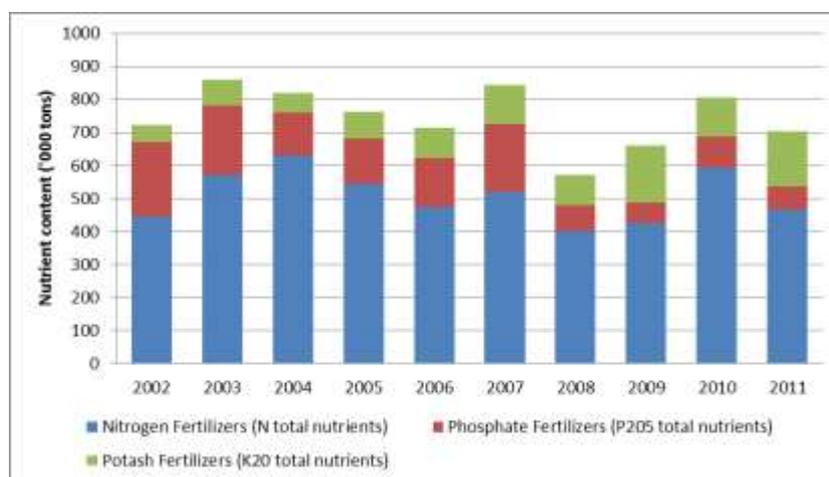
Source: FAOStat.

2.2. Evaluating efficiency of fertilizer application

Agronomic criteria

One basis for evaluating inadequacy of N application is agronomically feasibility, i.e. fertilizer application rate to achieve a target yield. Sebastian, Bordey, and Alpuerto (2006) estimate the yield gap between soils under best cultural management and soils with

macronutrient deficiencies is 2 tons/ha for good seeds during the dry season. Gines et al (2004), in a study involving site-specific nutrient management (SSNM), find that SSNM involves 46% higher fertilizer cost compared to farmers' practice.

Technical efficiency

Agronomic feasibility is usually evalauted based on expert farming techniques on pre-selected experiment stations, or in selected farmer plots. One extension of this type of assessment is to incorporate more farmer- and plot-specific constraints, which is done in studies of *technical efficiency*. Denote output by y, the vector of inputs by $\mathbf{x}$, error terms v, u, and other nonstochastic variables $\mathbf{z}$ such that:

$$y = \exp(\mathbf{x\beta} + v - u); \; E = \exp(-u) = \exp(-\mathbf{z\delta} - W)$$

While v is a standard error term, assumed i.i.d., the error u has a half-normal structure, and represents departures from the production frontier, which is the ideal for technical efficiency. Umetsu et al (2003) found that a fall in the price of fertilizer (relative to land) has significant positive effect on technical efficiency. Very recently, Koirala et al (2015) ran a stochastic frontier analysis with fertilizer cost as an explanatory variable; they found the coefficient of fertilizer cost is negative and statistically significant. A one-percent increase in total fertilizer cost reduces technical efficiency by 2.85%.

There are however difficulties in the interpretation of measurement or even conception of "technical efficiency". It may perhaps be more appropriate to view inadequate N application one of allocative (as opposed to technical) efficiency. That is, supposing farmers are on average on the production frontier, they may still be falling short of optimal fertilizer application, based on economic (rather than technical or agronomic) criteria.

Allocative efficiency

The model of the profit maximization is an economic approach to account for benefits and costs of input application. Consider a stochastic production function involving two inputs, with input levels x_1, x_2, and output level y, such that $y = f(x_1, x_2)$ in deterministic form. Adding an random variable ε introduces the standard error term; suppose input prices are w_1, w_2 and the output price is p. The stochastic profit is therefore:

$$\pi = p[f(x_1, x_2) + \varepsilon] - w_1 x_1 - w_2 x_2$$

To maximize expected profit, then each of the inputs *i* should be utilized until the following is acheived:

$$p \frac{\partial f}{\partial x_i} = w_i \Leftrightarrow \frac{\partial f}{\partial x_i} = \frac{w_i}{p}$$.

The value of marginal product should equal the input price; or alternatively, the marginal product should equal the input price to output price ratio. That is, if kg of fertilizer is double the value of a kg of palay, then fertilizer should be used until the marginal product of a kg of fertilizer is 2 kg of palay. If marginal product is above the fertilizer-to-palay price ratio, fertilizer is being underutilized, hence more fertilizer should be applied; if below the fertilizer-to-price ratio, fertilizer is overutilized, hence less fertilizer should be applied.

In fact, Pingali et al (1998) found from rice farm studies that the marginal product of fertilizer in the Philippines is 15.3 kg during the wet season, and 8.3 kg during the dry season, compared to a fertilizer price/palay price ratio of 4.1. That is, fertilizer is being underutilized. In contrast, for Indonesian farms, where fertilizer application per ha is higher, the marginal product is closer to the fertilizer/palay price ratio.

More recently, Shively and Zelek (2003) also find that fertilizer application rates among a sample of Palawan rice farmers is far below what maximizes profit. Figure 5 reproduces one of their charts. The discrepancies are very large: farmers apply levels of only one-fifth to one-seventh of the optimal quantity of fertilizer.

Figure 5: Observed and optimal fertilizer application of Palawan rice farmers, kg/ha
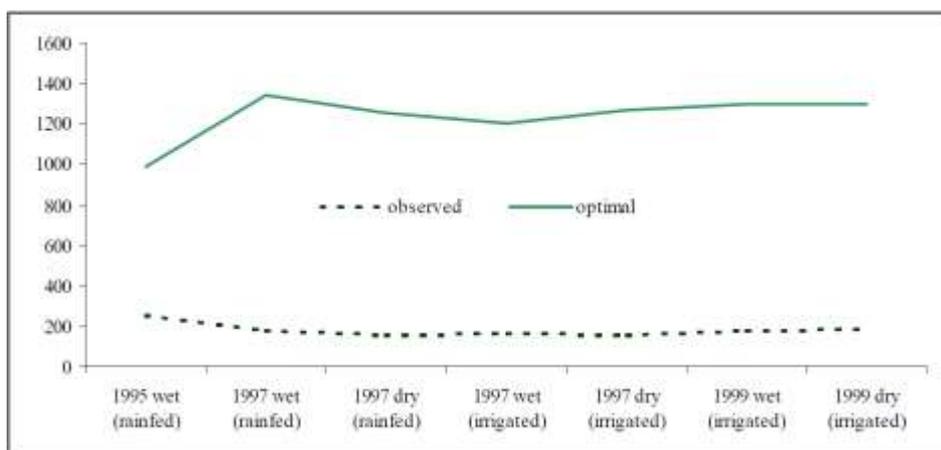
Source: Shively and Zelek (2003).

Likewise, Dawe et al (2007) find that rice farmers in four rice producing provinces throughout the country (Nueva Ecija, Laguna, Camarines Sur, and Iloilo) are under-applying

nitrogen fertilizer, compared with optimal levels of fertilizer application, in irrigated areas, and during the dry season. The optimal level is computed in terms of profit maximization given a dose-response function fitted to field experiments. The experiments suggest that farmers should be using 1 – 2 bags of urea more per ha. With proper levels of nitrogen fertilizer, farmers can raise yield by 1 ton of palay per ha, at least in irrigated areas.

Explanations for failures to maximize expected profit may be broadly classified into three sets, namely: external constraints, attitude towards risk, and internal constraints. *External constraints* pertain to access to credit, and inputs, e.g. reliable irrigation service. *Attitude towards risk* covers a broad set of possible behaviors, such as expected utility theory, where risk aversion arises from the mere curvature of the utility function, and utility is a continuous function of income; lexicographic safety first (LFS), which posits a threshold of loss or "disaster" which a farmer seeks to avoid; and prospect theory, which extends expected utility by introducing additional psychological elements (i.e. loss aversion and probability weighting).

Internal constraints are increasingly being recognized in the emerging literature of behavioral economics, referring broadly to *cognitive disagreement*, i.e. skepticism to the point of rejecting scientific advice about farming, as well as *action-intention gap*, i.e. failure to implement intentions (e.g. procrastination, regret spending, etc.) For the former, smallholders may be thinking in terms of *mental models* related to fertilizer efficacy; for the latter, smallholders may be thinking automatically when making spending decisions, displacing purchases of fertilizer with other expenses (World Bank, 2015).

2.3.   Explanations of inadequate N application

External constraints

The FSSP (DA National Rice Program, 2012) lists at least two explanations for inadequate N application, namely high fertilizer price, and lack of irrigation. An additional, commonly proferred explanation is lack of credit. High fertilizer price cannot be an explanation as prices are adequately incorporated in expected profit maximization; this leaves reliability of water supply, and credit. However Dawe et al (2007) find no relationship between N application and farmer's evaluation of water reliability; moreover, wealther farmers did not apply more N than poorer farmers. In short, neither water supply nor access to credit are satisfactory explanations for inadequate N application.

Attitude towards risk

Expected utility: diminishing marginal utility of income

Under expected utlity theory, agents objectively know the probabilities of various states of the world, but subjectively value levels of income. Behavior is explained by maximization of utility weighted by these probabilities, i.e. *expected utility*. Behavior exhibiting aversion to risk is a simple consequence of diminishing marginal utility of income. Expected profit maximization turns out to be a special case of behavior towards risk, called *risk neutrality*, where utility varies linearly with income.

Empirical measurement of risk aversion has been done for developing country agriculture. An influential early study was by Binswanger (1980) for villagers in rural India. He found that: a) at low pay-off levels, degree of risk aversion varies, widely, from risk neutrality, to risk aversion, to risk preference; b) at high pay-off levels, i.e. in the magnitude of monthly labor income, risk aversion is moderate, with virtually no risk neutrality present. He concludes that if risk aversion findings apply to farming decisions, then differences in investment behavior across farmers are not explained by differences in risk attitudes, but by other factors, e.g. access to credit, marketing, etc.

For the Philippines, Rosegrant and Roumasset (1985) have linked fertilizer use to the variance of the error term in a production function, i.e. allowing for heteroscedasticity, for which the estimation technique used is generalized least squares. They find that yield variability initially tends to *decline* as fertilizer application increases, though the relationship is U-shaped (i.e. varaibility eventually increases). Under a more realistic estimate of relevant parameters based on earlier studies, risk aversion explains just $10 - 17$ percent of the shortfall of N application compared to the risk-neutral case. Similarly, Abedullah and Pandey (2004), using data from rainfed areas only, find that moderate risk aversion accounts for just $5 - 14$ percent deviation from risk-neutral behavior.

Recently Lucas and Pabuayon (2011) conducted a survey of rice farmers to elicit risk aversion parameters using hypothetical lotteries. Likewise Domingo et al (2015), in a study of upland vegetable farmers, elicited risk aversion parameters using subjective rating, and hypothetical choices, with a distinction drawn between farmers at subsistence and above subsistence (Table 2). In both samples, majority of farmers are risk neutral to risk averse (though a surprisingly large minority share of farmers are risk preferring, i.e. 16% for rice farmers and $30 - 33\%$ for vegetable farmers). Clearly as majority of farmers exhibit nil to moderate risk aversion, and in conjunction with the findings reported earlier, inadequate N

application is not satisfactorily explained by curvature of the utility function under expected utility theory.

Table 1: Shares in sample farmers by study and risk aversion category (%)

Rice farmers, Northern Philippines		Vegetable farmers, Southern Philippines		
			Subsistence	
	Share		Assured	At-risk
Highly risk preferring	13	Risk averse	45	58
Very risk preferring	1	Risk neutral	25	9
Risk preferring	2	Risk preferring	30	33
Risk neutral	2			
Slightly risk averse	31			
Risk averse	4			
Very risk averse	8			
Highly risk averse	5			
Do nothing	36			

Sources: Lucas and Pabuayon (2011); Domingo et al (2015).

Lexicographic preferences: safety-first

An alternative to expected utility to explain risk avoidance is lexicographic safety-first (LSF), e.g. Kataoka (1963), with empirical application by Shahabuddin et al (1986). Define $\bar{d}$ as a disaster threshold, $\bar{\alpha}$ a probability threshold, and x a the net income from farming. The farmer adopts as first priority the following criterion of decision-making:

$$\Pr\left[\pi(x) < \bar{d}\right] \le \bar{\alpha}$$

That is, the farmer acts so as to prevent the probability of suffering a disaster below a threshold.

Work by Roumasset (1974) for the Philippines concludes however that lexicographic safety-first is not likely to explain low application of N. The main reason is that applying fertilizer raises the mean, without large increases in dispersion of yield; in fact to reduce risk of falling into disaster, the farmer should apply *more* rather than less fertilizer. Furthermore, if LSF causes farmers to reduce fertilizer application, then the apparent implication is instruments that reduce or eliminate the probability of disaster – such as crop insurance – should increase fertilizer application.

Prospect theory: loss aversion and probability weighting

Prospect theory (or "cumulative prospect theory") incorporates the following elements into the standard expected utility function (Tversky and Kahnemann, 1992):

- Reference point: the starting point of the agent is the basis for gauging gains and losses;

- Loss aversion: agents are especially sensititve to losses compared to gains;

- Overweighting of probability: small probabilities of loss are subjectively amplified.

As shown by Sheremenko and Magnan (2015), both loss aversion and risk aversion reduce the amount of fertilizer applied; underweighting of small probabilities of loss will cause more fertilizer to be applied; conversely, overweighting of small probabilities of loss will lead to lower application of fertilizer.

Tanaka, Camerer, and Nguyen (2010) were apparently the first to propose an experimental method for detecting prospect theory behavior in agriculture, together with other non-conventional time discounting behavior. Their experimental method was also used by Liu and Huang (2013) for Bt cotton farmers in China; a similar method was applied by Bocqueho et al (2014) on farmers in France. The latter find that farmers do value losses twice as much as gains of the same magnitude, i.e. loss aversion; and that farmers do overweight low probability extreme events. The authors conclude that design of agricultural policy should account for asymmetry between gains and losses; and exaggeration of low likelihood extreme events.

Internal constraints

Cognitive disagreement

Attitude towards scientific advice on fertilizer application may be roughly analogous to some types of attitude towards health observed in India: the unwillingness of some households to actively seek vaccination for their children is due to the inability of the households to understand the link between vaccination and disease. Acceptance of vaccination by such households will depend on its level of trust in the service provider, rather than on any prior knowledge (Das and Das, 2003).

As pointed out by Banerjee and Duflo (2011), even in Western countries, despite the prominent role of advanced science, some people find it difficult to base choices on hard evidence, and may continue to mistrust experts. In developing countries the constraints may be even worse, as most have not have rudimentary high biology, and may have little reason to trust the comptence of health professionals. Similarly, farmers may not be aware of rudimentary chemistry, and may have little reason to accept the recommendations of an agronomist or farm technician, relyin instead on first-hand experience, or second-hand accounts from neighboring farmers.

Action-intention gap

The action-intention gap has been recently applied to account for the low fertilizer application by farmers in Africa. The hypothesis is that farmers find it difficult to persevere in their intention to reserve money received after harvest to buy fertilizer during the next planting. Other household expenses, and perhaps other wants, compete for scarce attention and willpower. If so, a scheme that gives a farmers an option to make pre-commitment (i.e. pre-payment) for fertilizer should increase adoption of fertilizer. Such a scheme was precisely the subject of a randomized controlled trial in Kenya reported in Duflo, Kremer, and Robinson (2011). The study found that when farmers are given this option, with free delivery of fertilizer during the cropping season, there is a 64% increase in adoption of fertilizer. However, free delivery only, based on cash purchase, led to no significant increase in adoption. The action-intention gap serves as an additional hypothesis to explain inadequate N application by rice farmers in the Philippines.

2.4.   Implications for policy

The nature of the problem of inadequate N application will have different implications for policy, depending on whether the standard for inadequacy is agronomic or economic. If the former, then rational choice of farmers may be inconsistent with policy targets for rice yields, suggesting reconsideration of the latter. If the latter, then strategies need to be designed in accordance with the underlying causes of the inadequacy, whether due to external constraints, behavioral factors, or both. Carter et al (2013) has found that a subsidized fertilizer voucher scheme in Mozambique increases fertilizer use by only 15 kg, far lower than the predicted increase of 68 kg in the absence of other constraints. They conclude that these other constraints are preventing many farmers from making use of the voucher, though the exact reason - lack of information, liquidity constraints, skepticism over the efficacy of fertilizer, etc. – are outside the scope of their study.

A design of more effective policy will depend on the factors behind the inadequate application of N. The following makes a rough correspondence between the explanation and the appropriate strategy or policy approach:

Explanation	Appropriate strategy
Liquidity constraint	Plant-now pay-later scheme (zero cash upfront)
Irrigation service	Investments to improve irrigation service delivery
Aversion to risk	Promotion of risk spreading instruments, e.g. crop insurance

Explanation	Appropriate strategy
Safety first	Also promotion of crop insurance: amount of cover should be large enough to cover disaster loss
Cognitive disagreement	More persuasive strategy involving village plot trials
Financial discipline	Pre-paid scheme

These considerations point to the importance of correctly determining: i) whether there exists quantitatively significant deviation of actual from optimal N application; ii) if so, the major factor or factors behind the deviation.

3. Evaluating inadequacy of N application based on economic criteria

3.1. Method

Let $N,\ P,\ K$ represent nutrient application per ha for nitrogen, phosphorus, and potassium, respectively (in kg). Farmers do not purchase nutrients directly, but rather fertilizers of the following grades in the Philippines:

- Ammophos (16-20-0), i.e. Ammonium Phosphate
- Ammosul (21-0-0), i.e. Ammonium Sulfate
- Complete (14-14-14)
- Urea (45-0-0)

Let $j = 1, 2, 3, 4$ denote the aforementioned fertilizer grades, x_j the quantity of fertilizer of type j; $\alpha_{Nj}, \alpha_{Pj}, \alpha_{Kj}$ the nutrient content of grade j for nutrients $N,\ P,\ K$; p_j the fertilizer price of type j, and PP the price of palay. Based on dose response function $f(N, P, K)$, optimum fertilizer application is found by solving the problem:

$$\max_{N,P,K} \pi = PP \cdot f(N,P,K) - \sum p_j x_j$$

$$s.t.\ N = \sum_j \alpha_{Nj} x_j;\ P = \sum_j \alpha_{Pj} x_j;\ K = \sum_j \alpha_{Kj} x_j;$$

Optimum fertilizer rates obtained from the analysis were then compared to national statistics on actual fertilizer application rates, based on nitrogen application per year per unit area harvested.

The estimation method is similar to Dawe et al (2007). First, we estimate the dose response relationship between yield and fertilizer inputs under the quadratic function. Dummy variables were also incorporated in the equation to put into account seasonal, time and location

differences. Let Y represents yield, N, P and K represent the application rates of respectively, nitrogen, potassium, and phosphorus; $\beta_0, \beta_{1....}\beta_n$ represent parameters to be estimated; *s, d,* and *z* respectively represent vector of dummies for season (wet and dry), year of experimental trial, and location; and ε the error term with the usual properties. The estimating equation is:

$$Y = \beta_0 + \beta_1 N + \beta_2 P + \beta_3 K + \beta_4 N^2 + \beta_5 P^2 + \beta_6 K^2 + \beta_7 N \cdot P + \beta_8 N \cdot K + \beta_9 P \cdot K$$
$$+ s + d + z + \varepsilon \tag{2}$$

Equation (2) is used for the dose response function f in (1).

3.2. Data

The data on fertilizer application rates and yield to be used in the following analysis were extracted from the FAO Nutrient Response Database (FERTIBASE). This contains information on experimental trials in several farm stations carried out during the years 1977 up to 1980, which includes information on the location and season (dry and wet) when the trials were conducted. Locations include 15 provinces from the Philippines – Albay, Antique, Camaranes Norte, Camarines Sur, Ilocos Norte, Ilocos Sur, Iloilo, Isabela, La Union, Mindoro Oriental, Nueva Vizcaya, Pangasinan, Quirino, Sorsogon and South Cotabato. The total number of observations in the dataset is 21,886. Average values for yield and nitrogen application rate are 4.5 tons/ha and 59 kg/ha, respectively. For fertilizer price (P/kg), farmgate price (P/kg) and amount of fertilizer use (in 50 kg bags), data were taken from the PSA CountryStat dataset, for 2003-2013.

Parameter estimates obtained from least squares regression are presented in Table 1. Variables are statistically significant, except for Potassium, 1980 dummy, and interacted terms.

Table 2: Parameter estimates for the quadratic dose-response function

Variables	Coefficient	
Fertilizer variables		
Nitrogen	17.684	***
Potassium	-2.26	
Phosphorus	25.21	***
Nitrogen (squared term)	-0.061	***
Potassium (squared term)	-0.171	***
Phosphorus (squared term)	-0.104	***
Nitrogen-Phosphorus interaction	-0.18	
Nitrogen-Potassium interaction	0.13	
Potassium-Phosphorus interaction	0.05	
Location dummies (Albay omitted)		
Antique	-729.23	***

Variables	Coefficient	
Camarines Norte	-869.59	***
Camarines Sur	-938.99	***
Ilocos Norte	-1238.2	***
Ilocos Sur	-1047.6	***
Iloilo	-450.55	***
Isabela	-920.96	***
La Union	-469.27	***
Mindoro Oriental	-921.51	***
Nueva Vizcaya	-860.75	***
Pangasinan	-1020	***
Quirino	-211.89	***
Sorsogon	-614.85	***
South Cotabato	690.652	***
Season dummies		
Dry	104.062	***
Year dummies		
1978	120.523	***
1979	53.99	*
1980	-100.29	
Constant	4123.96	***

Note: Level of significance: *p<0.05, **p<0.01,***p<.0.001.

Source: Author's calculation.

Comparisons between the estimated optimal N application with actual fertilizer application are shown in Figure 6. Results from the quadratic function suggest that farmers apply only about three-fifths to two-thirds the optimal amount of nitrogen fertilizer. That is, to maximize profit, farmers should increase fertilizer application by 60 – 67%.

Figure 6: Percentage difference between actual and optimal N Application Rates
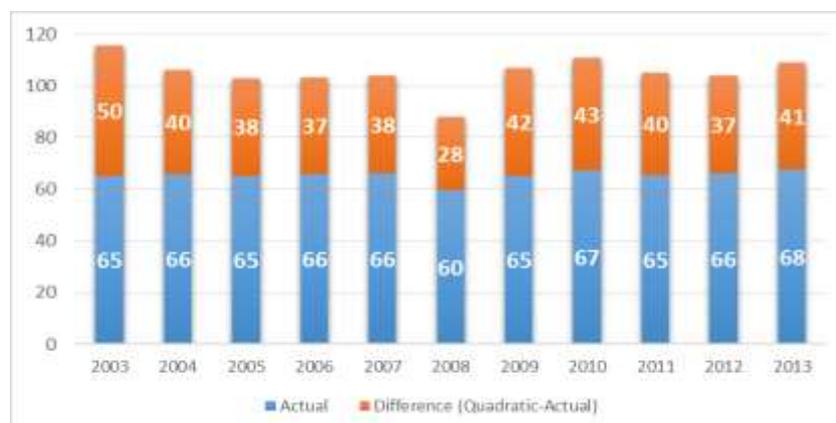
Source: Author's calculation.

Interpretation of the foregoing results must be done with care: as data used from the analysis came from experimental trials. A more complete analysis should estimate the production function using farm-level data.

4. Directions for further research

Further study will be conducted to evaluate and explain inadequacy of N application. The data will be drawn from a single large rice growing province to limit data collection cost. The natural choice is Nueva Ecija, the country's top producer of palay, located in Central Luzon, the country's "rice bowl". Over the past three years, this province alone (out of total of 81) has accounted for an average of 9% of palay production; it is widely acknowledged as the exemplar of rice growing in the country. Based on Dawe et al (2007), application of nitrogen fertilizer in Nueva Ecija in the wet season was at (or above) optimal, whereas application during the dry season is 23% below optimal.

4.1. Evaluating inadequacy of N application based on expected profit and utility

The evaluation performed in Section 3 uses experimental station data. The evaluation will be repeated on farm level data. The farm survey should preferrably have been conducted in Central Luzon, the country's rice bowl, which includes Nueva Ecija. For this purpose, the IRRI Central Luzon Loop Survey data will be utilized, available from http://ricestat.irri.org/fhsd/php/panel.php?page=3.

4.2. Evaluating the reasons for inadequate N application

Supposing the result of the analysis in Section 4.1 conforms with past literature and findings of Section 3.1. What remains is to explain the inadequate N application, based on external constraints, attitude towards risk, and internal constraints. To do this, primary data will be collected from Nueva Ecija by a farmer survey. The survey will be conducted to cover the past two cropping seasons; if conducted on January 2016, it will cover dry season 2014-2015 (December – January to March - April) and wet season 2014 – 2015 (May – June to August – September).

Survey design

The survey frame is the Nueva Ecija sample of the Registry System of Basic Sectors in Agriculture (RSBSA). The number of Nueva Ecija rice farmers (defined as reporting rice as top crop) is 69,615; however, dropping barangays where the number of rice farmers does not

exceed 10 leaves 69, 140 farmers (equivalent to 10% of barangays being dropped). Assuming a 95% confidence interval with a corresponding z-value of 1.96, a response distribution p equal to 50%, and margin of error e of 5%. The sample size n is 400, computed from the following formula:

$$n = \frac{z^2 p(1-p)/e^2}{1 + \left(\dfrac{z^2 p(1-p)}{e^2 N}\right)} = 382 \approx 400.$$

The sample of 400 farmers will be drawn by stratified random sampling. The levels of sampling are: municipal; barangay; and household. At municipal and barangay levels, samples are drawn based on PPS (probability proportional to size). To maintain cost-effectiveness, ten municipalities will be drawn. The barangay level is taken to be the primary sampling unit (PSU); according to Yansaneh (2005), supposing low intra-class correlation (e.g. 0.05), a sample of ten farmers from each PSU implies a low design (i.e. 1.05). Hence the design calls for 40 barangays, with four barangays drawn from each municipality.

At the selected PSU, farmers will be selected using the coverage approach. In this method, a reference point is identified in the barangay, i.e. a prominent landmark. Starting from the reference point, the enumerator visits every third house for interview, until the target number of respondents in the barangay is met. This method is being used by the Rice Based Farm Household Survey (RBFHS) of the Philippine Rice Research Institute (PhilRice).

Survey instrument

The instrument or questionnaire for primary data collection is appended as Annex 1. It is divided into nine sections, numbered by Roman numerals, with the following coverage:

Section I: Interview details

Section II: Farmer characteristics

Section III: Test of knowledge about nitrogen management

Section IV: Farmer assets;

Section V: Fertilizer application practices;

Section VI: Other farm costs

Section VII: External constraints

Section VIII: Internal constraints

Section IX: Lottery game

Section II characterizes other information that may account for fertilizer demand. Section III tests the farmer-respondent's knowledge about nitrogen management; it consists of ten multiple choice questions covering the basics of nitrogen fertilizer and its application. The score from this exam, and/or correct answers in specific questions (i.e. pertaining to calculating nitrogen content of specified quantities of fertilizers of different grades), will be used in assessing the role of information or knowledge in nitrogen application rates; it is properly part of the Section VIII on internal constraints, but should in an interview context be placed right after obtaining the farmer's personal profile. Section IV covers farmer assets, with a comprehensive description of farm parcels, together with other farm and personal property assets; the latter is used in conjunction with the credit information in Section VII to describe external, financial constraints. Section V elicits details on fertilizer application practices, together with fertilizer prices, while Section VI elicits other input prices (namely labor and machinery rental). Section VII covers financial, irrigation service, and crop insurance constraints. Section VIII covers information constraints, cognitive disagreement, as well as action – intention gaps.

The lottery game

The last Section of the questionnaire introduces a lottery game, based on Tanaka et al (2010). The respondent is presented with 35 possible lottery types, and is asked to select one of two options for each type. Each option corresponds to an actual lottery over two outcomes x and y, $|x| > |y|$, and respective probabilities p and $1 - p$. The pattern of choices of the respondent allows the researcher to calibrate risk aversion, probability weighting, and loss aversion parameters.

The underlying model is as follows: let v denote a pay-off function such that:

$$v = \begin{cases} x^{\sigma}, & x > 0 \\ -\lambda(-x)^{\sigma}, & x < 0 \end{cases}$$

The risk aversion parameter is σ and the loss aversion parameter is λ, $0 \le \sigma \le 1, \lambda \ge 0$. Suppose there is a probability weighting function $\pi(p)$; here the form is posited as

$$\pi = \frac{1}{\exp\left[\ln(1/p)\right]^{\alpha}}, \quad 0 \le \alpha \le 1$$

The value of the prospects are given by:

$$U = v(y) + \pi(p) \cdot v(x) + \pi(q) \cdot v(y). \tag{3}$$

In the special case of $\alpha = \lambda = 1$, (3) collapses into a standard expected utility function; if furthermore $\sigma = 1$, the farmer is risk neutral. The lottery types are divided into three sets: Set 1 consists of types 1 to 14; Set 2 to types 15 to 28; and Set 3 to types 29 to 35. In each set, in ascending order of lottery types, supposing the respondent has monotonic preferences (more is better than less), he/she will choose either B outright, or begin with A then switch to B thereafter. The values of *p*, *x*, and *y* are selected such that the switch points will allow the researcher to calibrate $\sigma, \alpha,$ and λ. See Tanaka et al (2010) for details.

Note that the lottery must be conducted as an actual game rather than hypothetical, as respondents' selections may be farther from their true preferences if choices are merely posited rather than actual. Elicitation of risk behavior parameters from field experiments on actual lotteries has a long precedent in the literature of behavioral economics; in agriculture, the foregoing literature review has cited relevant work by Binswanger, Tanaka et al, Liu et al., and Bocqueho et al (2014).

Explaining fertilizer demand

Using the primary data collected in the farm survey, the first step of the analysis is to compare nitrogen application rates across farmers, using tabular methods. Tabular comparison is based on the following:

- Location (i.e. municipality)
- Season
- *Schooling attainment*
- *Years of experience in farming*
- *Farmer assets*
- *Access to credit; terms of access (interest rate)*
- *Availability and adequacy of irrigation service*
- *Access to insurance; terms of access (premium rate and coverage)*
- *Score in the nitrogen fertilizer management test*
- *Difference between actual and planned spending on fertilizers, and reasons provided for difference*
- *Parameters of risk aversion, loss aversion, and probability weighting*

Comparison will also be done on yield performance and fertilizer application practice by timing, composition, and quantity, sample comparison will be done

The second step is to run a regression analysis with nitrogen application (in kg) per ha per season as the dependent variable, with explanatory variables drawn from the preceding comparison variables in italics, with the following additional variables: Palay price, in pesos/kg; and fertilizer prices for the four major grades (46 – 0 – 0; 21 – 0 – 0; 16 – 20 – 0; 14 – 14 – 14), in pesos/bag. Variables that account for low fetilizer application rates are those with negative and statistically significant coefficients. Regression takes the form of ordinary least squares, unless Breusch-Pagan test suggests the use of heteroscedasticity-consistent regression with robust standard errors.

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