Adverse Selection in Developing Country Factor Markets: The Case of Fertilizers in Cambodia

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Abstract:
We analyze the presence and potential impact of low quality fertilizers, inadequate access to credit and market information on fertilizer market participation and application rates. We explain in theory and show empirically that farmers chose to abstain from the fertilizer market altogether or decrease their application rates below recommended levels because bad quality deters all buyers not willing to pay the market price for the average quality fertilizer available.

Key words: asymmetric information, adverse selection, quality
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Developing country factor markets are often fragmented and inadequately reflect supply and demand conditions. Many studies have analyzed agricultural factor markets in developing countries and information deficiencies have been cited as an important reason for factor market inefficiencies. In this study, we analyze the effects of adulterated fertilizer supplies, insufficient access to credit, and limited market information on fertilizer application rates in different regions of Cambodia. In 1993, Cambodia became a democratic monarchy and has since experienced a significant degree of market liberalization characterized by the emergence of private traders meeting growing private demand. In the early years, the private sector fertilizer market grew rapidly from 200t in 1993 to 55,000t in 1996 while the share of the public market declined steadily (Yaptenco 1996).

FAO evaluated the performance of the public sector distribution system concluding that fertilizer stocks and distribution channels are poorly managed, overstaffed, and without proper technical skills leading to higher operating costs compared to private sector traders (FAO, 1995). Provincial distribution plans are implemented poorly and unreliable supplies do not meet actual demand. Many farmers prefer buying from private sector traders, even at higher prices, because of their relative reliability and accessibility of supply and service. The wholesaler/retailer network is relatively dense, ensuring proximity of service to need (Yaptenco 1996). However, there are also problems within the private market usually in terms of adulterations such as the sale of underweight bags, incorrect labels, or fertilizers mixed with sand or ash. Other problems hampering the private sector include informal road fees and limited and/or preferential access to credit only for selected farmers (Höngen and Suon, 1999). As a result, a significant amount of low quality fertilizers has surfaced in private markets that are either tainted or old and deteriorated. Among other reasons, the presence of low quality fertilizers has made many farmers suspicious buyers or to abstain from the market altogether and has contributed to fertilizer application rates well below recommended levels (Höngen, 2000). The phenomenon just described is an example of adverse selection, which characterizes transactions in which the seller has relevant information that the buyer does not have, or vice versa.

The main objective of the paper is to empirically investigate the presence and potential impact of adverse selection on fertilizer use in addition to other impeding factors such as insufficient access to credit and limited market information. The data used in the analysis was gathered from group interviews questioning 82 farmers in seven different regions in Cambodia participating in the Cambodia-IRRI-Australia Project (CIAP). We are able to show that farmers choose to abstain from fertilizer markets or decrease their application rates well below recommended levels because they have obtained bad quality stocks in the past, which in turn adversely affects all current buyers.

Granulated urea is the most common nitrogen fertilizer in wet rice production. In developing countries, it is typically sold in 20-50 kg bags. Granulated urea can be converted to ammonia on-site. The conversion rate depends on the nitrogen content. An important advantage of granulated urea is simple handling for delivery and storage. A disadvantage relative to liquid forms is the need for de-mineralized water to convert to ammonia. Other fertilizers applied include DAP (diammonium phosphate) and less importantly potash. The recommended application levels and times are purely technical in nature and are based on soil types and rice varieties determined through multi-year soil tests for the various rice growing regions (White et al, 1997). In general, the recommendation levels increase with soil fertility and the suitability to grow high-yield varieties. The recommendations have been published in a handbook used in training courses for farm advisors through the Ministry of Agriculture and are thus known even in remote areas (Heer et al, 1998).

According to the data, only about 70% of all farmers choose to apply urea, while about 30% abstain from such practices (see also Table 1).[1] Farmers that choose to apply urea use on average only 66% of the recommended application rate per hectare. Between regions, urea recommendations vary by a factor of three (or more than 100 kg/ha) while average application rates differ by a factor of ten (or more than 90 kg/ha ranging from 13% - 84% of recommendations). In absolute terms, Takeo and Kandal have the highest average urea application rates and the smallest discrepancy between recommendation and usage. Srey Veng has the lowest urea application rate, but the highest difference between recommendation and use. We employ simple market participation and

[1] Only 48% of all farmers choose to apply DAP (13% apply potash).

average application rates to draw conclusions with respect to the presence of adverse selection effects. This seems appropriate because of the large variation in the absolute and relative difference between recommended and actual urea application rates.

In the next section, we present a game theoretical model based on a simple adverse selection argument (Varian, 1999; Gintis, 2000). With a simple quality choice model, we explain how low quality fertilizer sales affect application rates because of uncertainty and information deficiencies. Farmers judge the quality of fertilizers sold in the market by the quality of past deliveries. Because current fertilizer quality is not easily observable, having obtained bad quality stocks in the past adversely affects all current buyers. A significant amount of distrust among farmers exists that they may obtain tainted low quality fertilizers in the marketplace. It deters all those buyers not willing to pay the market price for the average quality fertilizer available from purchases, which in turn will decrease the application rates below their recommended levels. In accordance with the theoretical model, we observe a significant lack of adequate higher quality fertilizer supplies in the market.

The Model

Consider a market, in which sellers (traders) know all about the value of their product (e.g. fertilizer), but the buyers (farmers) only know the distribution of product quality. For simplicity, suppose that all agents are risk neutral and the (quality determined) fertilizer value for one unit v is a random variable uniformly distributed between $[v_l, v_h]$, where $0 < v_l < v_h$. Moreover, assume that the reservation price for traders is $f\,v$, that $0 < f < 1$, that f is the same for all traders and that all farmers know f. For farmers, the choice is then to offer a price p. For traders, it is a best response to accept any price $p \geq f\,v$. If we assume perfect competition, each farmer will offer a price $p=E[v|p]$ or the expected fertilizer value assuming the trader is willing to sell at that price. In such a market, Pareto-optimality is achieved when all fertilizer values $[v_l, v_h]$ are sold, which requires $p > f\,v_h$. In this case, the expected fertilizer value is $E[v|p] = (v_h + v_l)/2$ which should be equal to p :

[1] $$p = \frac{v_h + v_l}{2} \geq f\,v_h \quad \Rightarrow \quad f \leq \frac{1 + v_l / v_h}{2}.$$

However, we are more interested in what fraction of fertilizer values is sold in general.[2] If equation [1] fails, the range of fertilizer values on offer will shrink. To see this, let *V(v')* be the event "true fertilizer value $\leq v'$ " and *S(p)* be the event "trader willing to sell fertilizer for price *p*." Then, for the range of reservation prices $f\,v_l \leq p < f\,v_h$, we have

$$Pr[V(v')|S(p)] = \frac{Pr[V(v') \,\&\, S(p)]}{Pr[S(p)]}$$
$$= \frac{Pr[S(p)|V(v')]\; Pr[V(v')]}{Pr[S(p)]}$$
$$= \frac{Pr[S(p)|V(v')]\; (v' - v_l)/(v_h - v_l)}{(p/f - v_l)/(v_h - v_l)}$$
$$= \frac{Pr[S(p)|V(v')]\; (v' - v_l)}{(p/f - v_l)}$$

The last expression defines the uniform distribution on the interval $[v_l, p/f]$:

[2] $$\frac{Pr[S(p)|V(v')]\; (v' - v_l)}{(p/f - v_l)} = \begin{cases} 0 & \text{for} \quad v' > p/f \\ (v' - v_l)/(p/f - v_l) & \text{for} \quad f\,v_l \leq v' \leq p/f\,. \end{cases}$$

Thus, in case equation [1] fails, i.e. $f > (1 + v_l/v_h)/2$, farmers will purchase fertilizer if and only if $p \leq \frac{p/f + v_l}{2}$ and the only possible Nash equilibrium yields a price $p = \frac{p/f + v_l}{2}$ or $p = \frac{v_l}{2 - 1/f}$.

Hence, the range of fertilizer values on offer will be $[v_l, v_l/(2f - 1)]$, which implies that as $f \rightarrow 1$, the interval shrinks in length to zero. This result would be Gresham's Law in action: bad value fertilizer drives out the good.[3]

In the next step, we present our empirical argument in an effort to show the presence and potential impact of adverse selection on market participation and fertilizer use in addition to other impeding factors such as insufficient access to credit and limited market information. During the data gathering investigation, we used qualitative and quantitative group interviews questioning 82

[2] Notice that in order to have any fertilizer values sold at all, we must have $p > v_l$.
[3] Named after Sir Thomas Gresham (1519-79) being the first to state the economic principle that bad money drives out the good, i.e. when depreciated, mutilated, or debased coinage (or currency) is in concurrent circulation with money of high value in terms of precious metals, the good money is withdrawn from circulation by hoarders.

farmers in seven different regions that participated in this Cambodia-IRRI-Australia Project (CIAP). From the interviews, we obtained the following data: whether the farmer applies artificial fertilizer [abstain: no = 0, yes = 1], the amount of fertilizers applied per hectare, simple qualitative indicators for having obtained low quality fertilizers during the past two years [adulteration: no = 0, yes = 1] and having access to market information in addition to the technical recommendations [market info: no = 0, yes = 1], as well as a very simple normative indicator for having access to credit [credit: no credit = 0, some credit = 1, enough credit = 2]. We also obtained information on the recommended levels of fertilizer application [recommend. (kg/ha)] and calculated the market participation ratio [participate (%)] for each region. Table 1 lists more detailed regional characteristics including yields and the percentage of urea recommendations which was actually applied by farmers.

The data was first used to estimate a simple logistic regression model. The discrete dependent variable is whether or not farmers apply urea fertilizer [abstain]. The independent variables are whether farmers have obtained low quality fertilizers in the past [adulteration], the normative indicator for how easy they have access to credit [credit], and the market participation ratio [Participate] as an indicator for how likely farmers in a particular region are to use urea fertilizer. We expect a positive impact of adulteration variable because having had a bad experience in the past should favor the current decision to abstain from the urea market. We would anticipate a negative impact on the decision to abstain if many other farmers in a given region already use urea fertilizers which would mean that the traders in that region are relatively trustworthy. We also expect a negative impact if access to credit is relatively easy for farmers. The regression results confirm these expectations and indicate a statistically significant relationship between the decision to abstain and the adulteration variable conveying the adverse selection information, as well as the indicators for ease of credit access and regional market participation (Table 2). All likelihood-ratio and Wald-test statistics are significant. The predictive power of the logistic model as shown in the classification table is good. The estimated odds ratios indicate that abstaining from the market becomes much more likely given a past adulteration event, while it becomes very unlikely given easy access to credit and a high market participation ratio in the region.

In a second, multivariate regression, we estimate the impact of the indicators for adulteration and credit access, and whether farmers have access to market information [market info] as well as a categorical regional dummy variable on urea application rates per hectare. For this regression, we estimate two models. The first includes all farmers in the sample while the second only includes those that do not abstain from the artificial fertilizer market and apply at least some urea.

The results of this regression indicate a statistically significant relationship between urea consumption and adulteration variable conveying the adverse selection information (Table 3). Moreover, we also obtain statistically significant relationships between urea application and having adequate access to credit and market information, as well as for all except one of the regional dummy variables. The signs of the regression coefficients are as expected, i.e. adequate access to credit and adequate market information both increase urea application (by about 29 and 32 kg per ha, respectively) whereas having obtained bad quality fertilizers in the past (adulteration) decreases urea application rates (about 22 kg per ha). The regional impacts amount to decreases in urea consumption between 40 and 60 kg per ha relative to the base region (Kandal). For the second model including only urea users, the results are similar but the adulteration variable becomes insignificant.

Conclusions

In this paper, we analyze the presence and potential impact of low quality fertilizers, inadequate access to credit and market information on fertilizer market participation and application rates. We show empirically that farmers chose to abstain from the market altogether or decrease their application rates below recommended levels because bad quality deters all buyers not willing to pay the market price for the average quality fertilizer available. Adequate access to credit explains most of the variation of urea consumption. Moreover, the results of the qualitative group interviews also show that adulteration, the lack of credit and a lack of adequate market information decreases urea application mainly for poor smallholders in remote areas who are not involved in any training or credit programs. Given the regional disaggregation, a clear shortcoming of the empirical analysis is the relatively small sample size. Comments on this first draft are anticipated and very welcome.

Table 1: Regional Characteristics

Province	observa-tions	yield (t/ha)	Urea Use participate (%)	recommend. (kg/ha)	average (kg/ha)	% applied of recommend.
Kampong Cham	11	0.882	45.5%	75	42.0	56.0%
Kampong Chnang	7	1.793	57.1%	50	28.8	57.5%
Kandal	19	3.105	100.0%	150	102.6	68.4%
Phnom Penh	9	2.156	88.9%	75	41.9	55.8%
Prey Veng	15	1.573	53.3%	75	45.6	60.8%
Srey Veng	7	0.913	14.3%	75	10.0	13.3%
Takeo	14	1.814	92.9%	100	84.2	84.2%
Total	82	1.903	70.7%	----	70.3	66.4%

Source: Höngen and Suon, 1999.

Table 2: Logistic Model [dept. variable: abstain (0,1)]

Maximum Likelihood Estimation

Parameter	Estimate	Std. Error	Wald-test	Est. Odds ratio
CONSTANT	1.68	1.23		
Credit	-1.98	0.84	5.51	0.138
Adulteration	4.22	1.37	9.44	68.24
Participate	-5.84	1.78	10.78	0.0029

Analysis of Deviance

Source	Deviance	d.f.	P-Value
Model	53.0507	3	0%
Residual	46.0932	78	99.85%
Total (corr.)	99.144	81	

McFadden Pseudo R^2 = 53.5% (adj. = 45.4%)

Classification

Observed	Predicted 0	1	% Correct
0	53	5	91.4%
1	4	20	83.3%
Overall %	69.5%	30.5%	89.0%

Likelihood Ratio Tests

Factor	Chi-Square	d.f.	P-Value
Credit	7.276	1	0.70%
Adulteration	18.116	1	0%
Participate	14.722	1	0.01%

Source: Own Calculations

Table 3: Multivariate Model [dept. variable: urea consumption (kg/ha)]

	All farmers			Urea users only		
Parameter	**Estimate**	**t-Statistic**	**P-Value**	**Estimate**	**t-Statistic**	**P-Value**
Constant	57.2*	4.58	0%	51.8*	3.60	0%
Credit	30.0*	4.54	0%	29.4*	3.55	0%
Adulteration	-22.8*	-3.53	0%	-13.4	-1.63	11%
Market Info	32.8**	2.11	4%	39.3**	2.34	2%
Takeo	-7.2	-0.74	46%	-2.4	-0.23	82%
Kampong Chnang	-40.6*	-2.88	1%	-34.5**	-1.97	5%
Kampong Cham	-49.5*	-4.45	0%	-31.2**	-2.12	4%
Prey Veng	-59.7*	-6.26	0%	-45.3*	-3.77	0%
Phnom Penh	-48.1*	-4.40	0%	-45.7*	-3.86	0%
Srey Veng	-48.1*	-3.27	0%	-57.9**	-2.02	5%
	n = 82 F-Ratio = 23.3 R^2 = 74.4% R^2 (adj. for d.f.) = 71.2% Std Error of Est. = 25.8 Mean absolute error = 18.8 DW statistic = 1.90 (P=0.095)			n = 58 F-Ratio = 10.5 R^2 = 66.4% R^2 (adj. for d.f.) = 60.1% Std Error of Est. = 26.9 Mean absolute error = 18.2 DW statistic = 2.00 (P=0.185)		

* and ** indicate significance at the 1% and 5% level, respectively.
Source: Own Calculations.

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