The Role of Pesticide Traders in Protecting Farmers and the Environment

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Abstract

We apply a switching regression estimation method to show that input traders in many ways play the substitute role of the public extension agents in a developing country. Owing to the inadequacy of the public extension services, farmers in developing countries often rely on the suggestions of agricultural input traders. As profit-making agents, these traders, in their turn, may have an incentive to exploit farmers by suggesting relatively expensive inputs. We collect primary information from 379 farmers in Bangladesh in two seasons. We then apply the Endogenous Switching Regression (ESR) estimation procedure to predict farmer's expenditure on pesticides, conditional on whether they rely on traders' advice. Our findings suggest that pesticides expenditures are not statistically different between the farmers that depend on traders' suggestions and those that do not. We conclude that by providing unbiased, helpful information to the client farmers, profit-maximising agricultural input traders render public extension workers' services, correcting possible market failures. Expanding the number of registered agricultural-input traders and integrating them in the public extension programs against misuse and overuse of agricultural inputs, such as pesticides by farmers, would be an effective market-based environmental policy in developing countries.

Key words: Pesticide trader, Bangladesh; Environment, Endogenous Switching Regression.

JEL Classification: D820, Q120, Q160

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I. Introduction

Owing to the inadequacy of public extension services, farmers' in developing countries often rely on agricultural-input traders for advice on input usage. Their opinion is sought regarding the input type, quantity to be applied, and timing of application. However, traders are commercial profit-making agents. Because of asymmetric information, in which traders possess more knowledge of inputs, such as pesticides and herbicides, they are likely to have an incentive to exploit farmers by suggesting excessive use of relatively expensive inputs. Such potentially dishonest behaviour of the traders can be viewed as a principal-agent problem that can partly be mitigated through a mutual trust from repeated transactions between the farmers (principal) and the traders (agent) in a strong social relationship (Arrow 1968; Otsuka and Hayami 1988). At the same time, by disseminating useful market information, the traders serve the useful role of reducing search and transaction costs both in the farm (Miyata, Minot, and Hu 2009; Key and Runsten 1999) and non-farm sectors (Mottaleb and Sonobe 2011; Hayami and Kawagoe 1993).

However, very few studies examine the role of traders as extension agents and whether traders exploit farmers while providing them with market information. Using information collected from 379 rice farmers in Bangladesh in the 2012-13 and 2013-14 *boro* rice seasons, this study examines the role of pesticide traders as agricultural extension agents in developing countries. This study examines whether or not agricultural-input traders exploit farmers by suggesting relatively expensive pesticides to them. We predict expenditures on pesticides of the sampled farmers, based on whether or not they rely on traders or other sources of information, such as government extension agents, own experiences, or suggestions of neighbouring farmers (peer experience) in deciding pesticide applications.

To put some historical context, Wilcoxson et al. (1975), in their authoritative commissioned report, stated that farmers of Bangladesh were using lower amounts of pesticides than the required amount. The authors ascribed it to the farmers' lack of pesticide knowledge. By 2018, however, Bangladesh is one country that uses massive amounts of pesticides (BBS 2018). In 1990, the net cultivated land in Bangladesh was 8.2 million ha (BRRI 2019a), and with 0.15kg/ha pesticides application rate, the total pesticides used in 1990 was 1,266 tons (FAO 2019b). In 2017, the net cultivated land in Bangladesh was 7.9 million ha (BRRI 2019a). The pesticide application was 15.5 tons (FAO 2019b), implying that the pesticide application rate was 1.9kg/ha. These numbers suggest that pesticide application intensified more than 12-fold over 26 years. As of October 31, 2019, 230 miticides, 1,018 fungicides, 2,495 insecticides; 695 herbicides, 18 bio-pesticides and 103 rodenticides and store grain products are registered and available in Bangladesh (BCPA 2019).

Currently, overuse and misuse of pesticides in Bangladesh and pesticide-related health and environment hazards are grave concerns (Rashid et al. 2003; Hasanuzzaman, Rahman, and Salam 2017; Sumon et al. 2016; Ahmed et al. 2019). For example, between May 31and June 30, 2012, 13 children died in Dinajpur District of Bangladesh because of the excessive and improper application of endosulfan insecticides to a lychee orchard (Renda 2017). Endosulfan is a highly toxic insecticide, which has been banned in more than 80 countries but is available in Bangladesh (Renda 2017). Rashid et al. (2003) claimed that pesticide traders were the primary source of information to farmers in deciding pesticide application in Bangladesh. Ironically, farmers who relied on pesticide traders, or government extension agents for information most likely overuse and misuse pesticides, compared to the farmers who relied on their own experience. The current research re-examines the issue, using data collected from 758 *boro* rice farmers in Bangladesh. Employing the Endogenous Switching Regression (ESR) estimation process, we estimate the predicted and expected expenditures on pesticides, based on whether or not farmers relied on traders' suggestions. Bangladesh is one of the champion countries in achieving self-sufficiency in rice food production by adopting modern high-yielding varieties (HYV), particularly in the *boro* season. As the HYV crops are highly responsive to irrigation, fertiliser and pesticides application, *boro* rice is considered one of the most pesticide-intensive crops in Bangladesh (Meisner 2004).

Knowledge regarding the dosage and timing of pesticide applications at different crop growth stages is crucial for the accrual of maximum benefits from use (Islam 2015). As farmers in Bangladesh depend on agricultural-input traders, government extension agents, and their own or peer experience, it is imperative to examine whether or not traders are exploiting farmers by recommending excessive or costly pesticides. Besides raising production costs, such behaviour can degrade the agroecology and environment.

2. Trends of pesticide use in Bangladesh

The application of pesticides in Bangladesh has been highly correlated with the adoption of rice and wheat's high yield variety (HYV) since the 1960s. In particular, the pesticide application has escalated dramatically with the rapid expansion of irrigated *boro* rice (Figure 1). Among the three varieties of seasonal rice crops, the adoption of HYV rice is the highest in *boro* rice (winter/ irrigated). The other two seasonal rice varieties are *aus* (summer/rainfed), and *aman* (rainfed). Currently, the proportion of the area under HYV in *boro* rice is more than 99.7%, 92% in *aus* and 87% in *aman* rice (BRRI 2019b). The scatter plots fitted regression lines, and non-parametric local linear regressions all indicate that the total pesticide application (metric tons) increased with the increase in the area under boro rice (000, ha) from 1994 to 2016 (Figure 1, panel (c)). In contrast, total pesticide use is negatively related to the area under *aus,* and *aman* rice cultivation.

[Insert Figure 1]

Initially, when HYVs of rice and wheat were introduced to Bangladeshi farmers, the application of pesticides was negligible. Following its independence from Pakistan in 1971, the government immediately implemented a 100% subsidy policy, completely free pesticide products. The subsidy was reduced to 50% in 1974 and removed completely in 1979 when the pesticide business was transferred to the private sector (GOB 2002). After removing the subsidy, although pesticide applications were initially reduced, their use has increased dramatically in years. For example, the total application of pesticides increased almost 30 times from a meagre 1.3 thousand metric tons (MT) in 1990 (FAO 2019b) to 37.2 thousand MT in 2017 (BBS 2018). A comparison of pesticide applications per hectare among selected Asian countries reveals alarming numbers. In 1990, pesticide application per hectare in Bangladesh was 0.13kg; compared to 0.44kg in India, 0.83kg in Sri Lanka and 0.02kg in Myanmar (FAO 2019a). In 2016, the per hectare pesticide application in Bangladesh increased to 1.87kg; in India, it reduced to 0.3kg; steady in Sri Lanka at 0.84kg and at 0.97kg in Myanmar (FAO 2019a). The increase in the growth rate of pesticide application in Bangladesh far exceeds the growth rate of other Asian countries.

3. Survey design, sampling and data

This study relied on data sets collected by the International Maize and Wheat Improvement Center (CIMMYT) in 2015. From April 22 to June 8, 2015, CIMMYT Bangladesh conducted a survey focusing primarily on crop production, irrigation water pricing, input application that includes fertilisers and pesticides from 556 households in 4 divisions during two *boro* rice seasons: 2012-13 and 2013-14 (N=1,112, n=556, T=2). Details of the sampling and data collection procedures are available in Mottaleb et al. (2019).

A telephone survey was then conducted during May and June of 2016 to collect supplementary information on trade names of the pesticides, mode of transaction with pesticide trades (e.g., credit or cash, repeated transactions), and social relationship indicators between the sampled farmers and pesticide traders. Out of the original 556 farm households, we reached 379 farm households in the follow-up telephone survey. We report these pesticide expenditures in Table 1. The other 177 unreachable households probably changed their mobile sim card or shut their mobile phones, or moved away from their villages. On average, a sampled farm household spent Bangladesh Taka (BDT)[1] 2,729 per ha on pesticides with significant regional variations, as noted in Table 1.

[Insert Table 1]

3.1 Data descriptions and descriptive findings

Nearly 55% (416) of the sampled households relied on traders' suggestions to decide on pesticide type (brand), dosage and timing of application (Table 2). This finding is supported by Rahaman et al. (2018), who also claim that farmers in Bangladesh generally sought advice from pesticide traders. Very few farmers communicate with public extension agents for this information. The other 45% (342) of sampled farm households relied on the government agricultural extension officers or their own experience or their neighbour's suggestions (peer experience). In Table 2 and subsequent tables, background information of the sampled households and input application patterns are presented to highlight whether the household heads relied on traders' recommendations

[1] Currently the exchange rate is USD 1= BDT 85, approximately.

in pesticide application. Each sampled household, on average, cultivated 0.89 ha of land in a sampled year, in which 0.22 ha were *boro* cropland (Table 2, Column 1).

[Insert Table 2]

The second and third columns of Table 2 present background information of the sampled households separately based on their information sources for pesticide applications. The fourth column of Table 2 presents the statistical differences of the selected background information variables based on whether or not a household relied on traders for information on pesticide application. Households that relied on traders' information for pesticide application operated statistically significantly less land than those relying on extension workers. In general, information from the government is cost-free and supposed to be more reliable.

[Insert Table 3]

Table 3 presents the input application behaviour of the sampled households. An analysis of the statistical differences in the input application behaviour based on whether not households relied on traders' suggestions is also presented (Columns 2-4, Table 3). The expenditure on pesticides alone and combined spending on pesticides and herbicides per hectare were not significantly different among the sampled households based on whether they relied on traders' suggestions in deciding on pesticide applications. The average rice yield (ton/ha) at 6.5ton/ha was the same between households that relied on traders or government extension agents for suggestions on pesticides application (Table 3).

[Insert Table 4]

The information on the trade and group names of the pesticides that farmers applied is reported in Table 4. On average, 20% of the sampled households (152) used pesticides categorised as highly hazardous by the World Health Organization (WHO 2010). The numbers in the table indicate that the acceptance rate of traders' information and suggestions on pesticide application is comparable to the suggestions of the government extension agents.

Interestingly, around 38% of the sampled households applied pesticides categorised as slightly hazardous, and nearly 14% applied pesticides in which no acute hazards are known to exist in their normal use (Table 4). Pesticides for *boro* rice are mainly applied to protect crops from brown planthopper, yellow stem borer, shoot and fruit borer, and cutworm.

4. Econometric estimation process

4.1 Conceptual framework and model specification

The objective of this study is to examine the source of differentiated pesticide expenditure at the household level. Although insufficient information from public extension agents is the primary reason to rely on traders' suggestions, a farmer's decision to rely on traders' suggestions may not be completely exogenous. Environmental and social factors and heterogeneity in the resource endowment of the farmers can influence the sources of information that a farmer will rely on to decide on pesticide applications. We assign the choice of advice on pesticide application to be a binary option variable (I_i= 1 if trader and 0, otherwise). A cost-minimising farmer then relies on the source of information that can be expressed as follows:

$$\left.\begin{array}{l} I_i = 1 \; if \; \theta z_i + u_i > 0 \\ I_i = 0 \; if \; \theta z_i + u_i \leq 0 \end{array}\right\} \quad (1)$$

where z_i is a vector of variables representing household-level and production domain-level variables that influence whether or not a farm household relies on traders (I_i= 1) or other information sources (I_i= 0) in deciding pesticide applications. θ is a vector of parameters to be estimated. As the expenditure on pesticides can be different based on the source of information a farm household relies on, the pesticide expenditure behaviour of a farm household now can be written as:

Regime 1: $EP_{1i} = X_{1i}\beta_1 + \varepsilon_{1i}, if \; I_i = 1$ (2): relies on traders′ suggestions

Regime 2: $EP_{2i} = X_{2i}\beta_2 + \varepsilon_{2i}, if \; I_i = 0$ (3): relies on suggestions other than traders where EP_{1i} , EP_{2i} represents per hectare expenditure on pesticides for farmers relying on the suggestion of traders and those other than traders, respectively. X_{1i} and X_{2i} are vectors of variables that include household-level and production domain-level variables that influence the expenditure on pesticides. β_1 and β_2 are vectors of parameters to be estimated for regimes 1 and 2. Following Lokshin and Sajaia (2004), we employed the Endogenous Switching Regression (ESR) estimation procedure to estimate equations (1-3). By utilising the ESR model estimation process, we then calculated:

- the average expected expenditure on pesticides of the households that relied on trader's advice = $E(EP_{1i}|x_{1i}) = x_{1i}\beta_1$ (4)

- the average expected expenditure on pesticides of the households that relied on advice other than traders' = $E(EP_{2i}|x_{2i}) = x_{2i}\beta_2$ (5)

- the conditional expectations - the expected pesticide expenditure of the households that relied on traders' advice = $E(EP_{1i}|I_i = 1, x_{1i}) = x_{1i}\beta_1 + \sigma_1\rho_1 f(\gamma z_i)/F(\gamma z_i)$ (6)

- the conditional pesticide expenditure of the households that relied on advice other than traders = $E(EP_{2i}|I_i = 0, x_{2i}) = x_{2i}\beta_2 + \sigma_2\rho_2 f(\gamma z_i)/\{1 - F(\gamma z_i)\}$ (7)

- the counterfactual pesticides expenditure of the households who currently rely on traders' advice, but if they would rely on advice other than traders'

$$= E(EP_{1i}|I_i = 0,\ x_{1i}) = x_{1i}\beta_1 + \sigma_1\rho_1 f(\gamma z_i)/\{1 - F(\gamma z_i)\} \quad (8)$$

and

- the counterfactual pesticide expenditure by the households that are currently relying on other than traders' advice, if they would rely on traders' advice

$$= E(EP_{2i}|I_i = 1, x_{2i}) = x_{2i}\beta_2 + \sigma_2\rho_2 f(\gamma z_i)/F(\gamma z_i)\} \quad (9)$$

where, $\rho_1 = \sigma_{1u}^2/\sigma_u\sigma_1$ is the correlation coefficient between ε_1, and u_i and $\rho_2 = \sigma_{2u}^2/\sigma_u\sigma_2$ is the correlation coefficient between ε_2, and u_i. F is a cumulative normal distribution function, and *f* is a normal density distribution function.

Note that the expected expenditure can be directly estimated from (6) and (7), but those from (8) and (9) are hypothetically calculated counterfactual outcomes. Following a procedure by Alene and Manyong (2007), we use equations (6) - (9) to calculate below the net impact on the pesticide expenditure due to the reliance on the advice of traders (10), and other than traders (11) for pesticide application decisions. This way, (10) and (11) are the calculated average treatment effects on the treated households (ATT) and the untreated households (ATU), respectively.

ATT= (6) - (8)

$$= E(EP_{1i}|I_i = 1,\ x_{1i}) - E(EP_{1i}|I_i = 0,\ x_{1i}) \quad (10)$$

ATU = (9) - (7)

$$= E(EP_{2i}|I_i = 1, x_{2i}) - E(EP_{2i}|I_i = 0, x_{2i}) \quad (11)$$

Besides, even assuming the same level of returns of the resources (β_i), the structural heterogeneity in the resource endowment (x_{Ji}) among the sampled farm households can also influence the choice of the source of information on pesticide applications, and therefore, the expenditure on pesticides. These different pesticides can be regarded as base heterogeneities (e.g., Mishra et al. 2018). In this study, the base heterogeneity (BH) or the pre-existing heterogeneity among farmers that rely on traders' advice to decide on pesticide applications is calculated as BH= Eq. (6)- Eq. (9), and for the farm households that rely on advice other than traders' to decide pesticide applications is calculated as BH= Eq. (7)- Eq. (8). In addition to base heterogeneity, this study calculates transitional heterogeneity as ATT- ATU.

For the empirical part, in estimating the function explaining whether or not a farm household relies on trader or government extension agents/own experience/peer experience in deciding pesticide applications, we have included the following variables in z_i, x_{1i}, and x_{2i}:

- age and years of schooling of the household head;

- a sex dummy that assumes a value of 1 if a household head is a female; and 0 otherwise;

- the total number of family members who are either engaged full time in agriculture or extend help in agricultural works;

- total land cultivated (ha);

- a self-perceived credit constraint dummy, which assumes the value 1 if a household head perceived himself as facing credit constraint, and 0 otherwise;

- a dummy for pesticides purchased on credit that assumes the value 1, if a household purchased pesticides on credit from the trader; and 0 otherwise;

- a season dummy *boro* season 2013-14 (yes = 1), setting *boro* 2012-13 season as the base (= 0);

- three-division dummies for four divisions setting Barishal division as the base (= 0).

In addition, in the estimation process, the vector of variables z_i includes environment domain variables that are treated as the exclusion variables. We assume these variables exclusively affect a household's decision on whether or not it relies on traders or other sources of information, but not the outcome variables, which is expenditure on pesticides. z_i includes:

- cumulative paved or gravel road (km) at the village level;

- a transaction dummy, that assumes a value of 1, if a farmer purchased pesticides from traders on credit, or 0 otherwise; and

- the number of markets in a five-kilometre radius of a sampled village.

Following Di Falco et al. (2011), we have conducted a falsification test to examine the exogeneity of the exclusion variables (Table 5). It reveals that three exclusion variables are statistically significant in the estimated function explaining the choice of advice on pesticide application sources by the sampled farm households. In contrast, all three variables are statistically insignificant in the estimated function explaining pesticide application (per ha) by the farmers who did not rely on traders' advice. Thus, the results in Table 6 support the exogeneity of the excluded variables.

5. Econometric findings

Before employing the ESR estimation procedure, we estimated the per ha pesticides expenditure of the sampled households by applying the Random Effect estimation procedure. We assumed the exogeneity of the sources of information from traders or others, which a household relied on. The estimated coefficient of the dummy for the household that relied on traders' advice for pesticides application (yes=1) is about -200, and it is insignificant. This indicates no statistical difference in the expenditure on pesticides by the sampled households based on whether or not they relied on traders' suggestions. The assumption of exogeneity of the sources of information that a household relied on for agricultural input application can be erroneous, as household's characteristics can influence the choice of the sources of information (e.g., Mottaleb, Rahut, and Erenstein 2019).

[Insert Table 5]

The estimated functions explaining the choice of the sources of information to decide on pesticide application ($I_i = 1$ if trader, 0 = other) and the pesticides expenditure (BDT/ha) conditional on the source of information are presented in Table 7. Age, sex, years of schooling and the number of family members of the sampled households have no statistically significant impact on the choice of the sources of information and pesticide expenditure. Interestingly, the household heads under credit constraints are less likely to rely on traders' suggestions in deciding on pesticide applications, but they spent significantly more on pesticides than others. It shows that the households in the sampled villages with improved infrastructure, such as more paved or gravel roads, are more likely to rely on traders' suggestions than others. More availability of markets discourages farmers from relying on traders' advice.

The significant Wald test (Wald Chi^2 (10) = 47.3, prob>Chi^2=0.00) indicating a good model fit (Table 6), and the significant likelihood ratio test Chi^2 (1) = 31.0, prob>Chi^2 =0, suggests that we can reject the null hypothesis of no correlation among the error terms of equations (1-3). These test results validate the application of the ESR estimation technique. The regression diagnosis (Table 6) further shows that the correlation coefficient Rho-1 is negative and significant, but the correlation coefficient Rho-2 is positive and insignificant. A negative Rho-1 suggests that the unobservable that not included in the model, which increases the probability of seeking advice from traders to decide on pesticide application, is negatively correlated with the unobservable that reduces the per hectare expenditure on pesticides.

[Insert Table 6]

Table 7 presents the predicted probabilities of choosing the sources of information. Conditional and unconditional expected pesticide expenditures based on the sources of information relied upon and corresponding treatment effects, including ATT, ATU, and base and transition heterogeneities, are also reported in Table 7. On average, there was a 54% chance that a sampled household will rely on traders for suggestions on deciding pesticide applications. The possibility that a sampled household will rely on suggestions other than traders', such as government extension agents, their own or peer experience, corresponding is 46% (Table 7). The unconditional linear prediction shows that, on average, a household that relied on traders' suggestions spent BDT 3,783.5/ha on pesticides. In contrast, it was BDT 2,896.8 in the case of a household that relied on information other than traders. The conditional expenditure on pesticides, however, revealed that, on average, a household that relied on traders' suggestions spent about BDT 2,665/ha on pesticides (cell a), and it was about BDT 2750/ha (cell b) in the case of a household that relied on other sources of information.

The last column of Table 7 presents the treatment effects (average treatment effect of the treated, ATT) of relying on information from traders on per hectare pesticide expenditure. Households currently relying on traders' advice would spend BDT 3,023/ha on pesticides (cell c), which is BDT 358.8/ha (13%) more had they not relied on traders' suggestions. The findings may not be surprising when one considers the case of community failure. Traders are probably providing necessary, helpful information and suggestions relating to the application of pesticides to their clients. However, the same traders may not offer appropriate suggestions to the farmers, who currently rely on suggestions other than the traders.

Overall, the findings in Table 7 demonstrate that the pesticide traders in Bangladesh provide necessary useful information to their clients. Their service quality on pesticide application is at least as useful as the information from the government extension agents and other sources.

[Insert Table 7]

6. Conclusion and policy recommendations

Misuse and overuse of pesticides and pesticide-related environmental and human health hazards are major national concerns. Currently, Bangladesh is one of the most intensive pesticide-using countries in the world. Lack of public agricultural extension services prompts many farmers to rely on the suggestions of pesticide traders in deciding pesticide dosage to be applied in crop production. Rahaman et al. (2018) found that pesticide traders were the primary source of information to farmers in deciding on pesticide application in Bangladesh. Ironically, farmers who relied on pesticide traders, or government extension agents for information, are most likely to overuse and misuse pesticides, compared to the farmers who relied on their own experience.

This study demonstrates that the increasing application of pesticides in Bangladesh is highly correlated with the rapid expansion of *boro* rice cultivation. Nearly 55% of the sampled farm households relied on pesticide traders' suggestions to decide on the pesticide applications' dose, type, and timing. Remainder 45% of the sampled farmers relied on government extension agents or their own experience or peer experience for such information. We found no significant differences in the human capital and physical capital endowments of the sampled farmers based on the sources of information they relied on in deciding on their pesticide application. This study revealed that traders are not suggesting highly toxic pesticides to their client farmers in comparison to the farmers who relied on suggestions other than traders'. Finally, the econometrics estimation of this study confirms that there are no significant differences in the pesticide expenditures based on whether or not a farmer relied on traders or other sources of information. Thus, this study refutes the claim that the suggestions of pesticide traders are responsible for the overuse and misuse of pesticides and the pesticide-related hazards in Bangladesh. Instead, this study re-emphasises the role of pesticide traders as a valuable source of information. Pesticide traders contribute to minimising farmers' production costs by suggesting acceptable pesticides and, therefore, indirectly protecting the ecology and the environment by preventing misuse and overuse of pesticides.

Based on the findings, this study suggests acknowledging the role of agricultural input traders as useful market information providers. An effective public agricultural extension program. The number should be inclusive of these input traders. Government-registered pesticide traders can be increased in rural areas where it is difficult to recruit public extension agents. This is not to undermine the provision of necessary public programs and interventions in the use of pesticides that has been increasing phenomenally.

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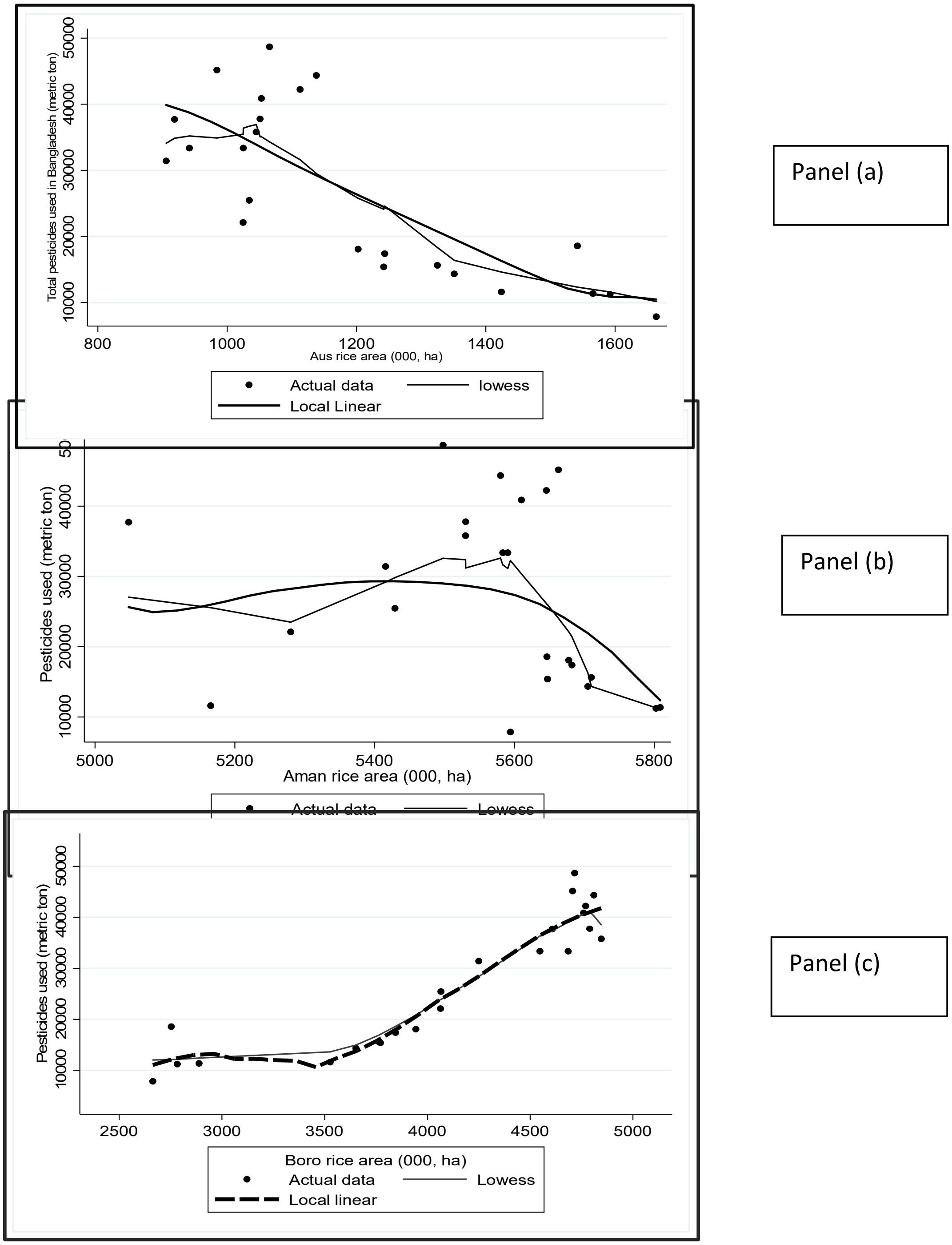

Figure 1: Scatterplot, lowess and local linear regression for pesticide use plotted against total area (000, ha) under *boro* rice in Bangladesh from 1994-2016.

Table 1: Sampled households and per hectare expenditure on pesticides (BDT) by location of the households

			Original survey, 2015	Follow-up telephone survey, 2016	
Divisions	Districts	Sub-district	Sampled households	Sampled households	Pesticides Expenditure (BDT/ha)
Barishal	Barishal	Babuganj	8	4	1801.8
		Barishal Sadar	16	9	2609.6
		Wazirpur	76	49	2977.8
	Bhola	Char Fasson	64	43	5259.8
	Jhalokati	Jhalokati Sadar	64	49	2645.5
	Pirojpur	Nazirpur	64	29	1991.3
	Patuakhali	Kalapara	64	45	1683.9
Dhaka	Madaripur	Kalkini	4	3	2012.6
		Madripur Sadar	4	3	2427.4
	Jamalpur	Melandaha	64	43	1780.4
Khulna	Jessore	Sharsha	64	48	2947.1
Rangpur	Dinajpur	Birol	64	54	2534
Total/average			556	379	2728.5

Source: Surveys, 2015, 2016.

Table 2: Background information of the sampled farmers by the source of information they relied on to decide pesticide applications

	All	Source of information		Kruskal-Wallis rank test Chi2 (overall differences)
	1	2	3	4
		Trader (a)	Other (b)	a≠b
No. of observations	N=758 (n=379, season=2)	416	342	
Age household head	45.0	44.4	45.5	1.28 (0.26)
Years of schooling household head	4.6	4.4	4.9	2.65* (0.10)
% Male-headed household	97.1	97.1	97.1	0.01 (1.00)
No. of family members	4.7	4.6	4.8	0.40 (0.52)
No. of family members involved in agriculture (full time and part time)	2.0	1.9	2.1	0.61 (0.43)
Total land cultivated in 2013-14 (ha)	0.89	0.85	0.92	2.71* (0.09)
Boro rice land (ha)	0.22	0.18	0.23	0.11 (0.74)
% Reported under credit constraint	52.0	50.0	53.2	0.42 (0.52)

Source: Authors' calculation based on Survey, 2015. *p*-values are in parentheses. * indicates significance level at 10%.

Table 3: Input application by the sampled farmers (per hectare) by the source of information they relied on to decide pesticide applications

	All	Source of information		Kruskal-Wallis rank test Chi2 (overall differences)
	1	2	3	4
		Trader (a)	Other (b)	a≠b
Men-day applied	177.0	180.0	173.8	0.20 (0.65)
Seed costs (BDT)	3,980.0	3,799.5	4,200.0	11.2*** (0.00)
Total chemical fertilizer applied (KG)	577.1	596.0	554.1	2.80* (0.09)
Expenditure on total chemical fertilizer (BDT	10,189.0	10,495.8	9,816.0	2.30 (0.13)
Urea applied (KG)	310.4	311.5	309.0	0.49 (0.48)
Expenditure on urea (BDT)	4,966.1	4,983.8	4945.0	0.49 (0.48)
Compost applied (KG)	848.7	1186.0	438.5	3.94** (0.05)
Expenditure on pesticides (BDT)	2,728.5	2711.0	2750.0	0.25 (0.62)
Expenditure on pesticides and herbicides (BDT)	5047.4	6421.0	3376.6	1.42 (0.32)
Yield (ton/ha)	6.5	6.5	6.5	0.30 (0.59)

Source: Authors calculation based on Survey, 2016

Table 4: Types and brand of pesticides and group names sampled farmers applied by the source of information they relied on when deciding on pesticide applications

Name of the pesticides/insecticides/fungicides used (group name)[b]	Hazard classification[C]	All	Information source farmers relied on		Pest/disease
			Trader	Other	
			No. of farmers reported (%)		
Furadan/Sunfuran (Carbofuran)	Highly hazardous	152 (20.0)	76 (18.3)	76 (22.2)	Brown plant hopper, Urfa, yellow stem borer
Basudin (Diazinon)	Moderately hazardous	58 (7.7)	32 (7.7)	26 (7.6)	Brown plant hopper, Urfa, yellow stem borer
Karate (Lambda Cyhalothrin)	Moderately hazardous	18 (2.4)	14 (3.4)	4 (1.2)	Cut worm
Cartap (Cartap)	Moderately hazardous	42 (5.5)	30 (7.2)	12 (3.5)	Shoot and fruit borer
Thiovit (Sulphur)	Slightly hazardous	8 (1.0)	6 (1.4)	2 (0.06)	Leaf scald
Virtako (Thiamethoxam, Chloraniliprole)	Slightly hazardous	284 (37.5)	166 (39.9)	118 (34.5)	Yellow stem borer
Rifit (Pretilachlor)	Unlikely to present any acute hazards	12 (1.6)	6 (1.4)	6 (1.8)	*Halde mutha,Pani kachu, Chechra, Bara Javani,*

Ronstar (Oxadiazon)	Unlikely to present any acute hazards in normal use	10 (1.3)	4 (0.09)	6 (1.8)	Herbicides
Proton (Synthetic Pyrethroid)	Not classified by WHO but no toxic effects[d]	18 (2.4)	10 (2.4)	8 (2.3)	Larva, helliothis, spodoptera
Did not apply any pesticide	--	52 (6.9)	28 (6.7)	24 (7.0)	
Other (Metro, Jhilik etc.) (Bensulfuran methyl and Acetachlor)	Unlikely to present acute hazard in normal use[e]	104 (13.7)	44 (10.6)	60 (17.5)	--
Total no. of farmers		758 (100)	416 (100)	342 (100)	

Sources: Telephone survey, 2016. [b](DAE 2013); [C](WHO 2010); [d](Thatheyus and Gnana Selvam 2013), [e](Pesticides Action Network 2012).

Table 5: Testing exogeneity of the exclusion variables: The falsification test

	Dependent variables	
Estimation process	Logit	Ordinary Least Square (OLS)
Exclusion variables	Relied on traders' advice in deciding pesticides application (yes=1, no=0)	Expenditure on pesticides (BDT/ha) if does not rely on traders' advice
Cumulative paved/gravel road (km.) at the sampled village	0.04*** (0.01)	25.4 (22.8)
A dummy for purchased pesticides on credit (yes=1)	-0.31** (0.15)	-383.9 (275.7)
No. of markets within 5 km radius of the sampled village	-0.44*** (0.08)	-75.4 (54.7)
Constant	0.81*** (0.15)	2994.5*** (237.7)
No. of observations	758	342

Numbers in parentheses are standard errors. *Significant at the 10% level, ** Significant at the 5% level and ***Significant at the 1% level.

Table 6: Functions estimated explaining the impacts of the source of information farmers relied on for deciding pesticides application and the expenditure on pesticides per hectare

Estimation model	Random effect	Endogenous Switching Regression (ESR)		
Dependent variables	Expenditure on pesticides (BDT/ha)	In deciding pesticide application	Expenditure on pesticides (BDT/ha)	
		Relies on traders; advice (yes=1, no=0)	Relied on advice from other than traders	Relied on traders' advice
Explanatory variables				
Age household head	1.57	-0.003	15.0	-13.9
	(10.89)	(0.01)	(16.55)	(13.47)
Years of schooling household head	24.18	-0.01	-8.57	31.8
	(26.15)	(0.02)	(31.29)	(43.74)
Female-headed household (yes=1)	843.5*	0.53	-119.9	876.5
	(423.13)	(0.47)	(534.70)	(666.28)
No. of family members extends	28.30	-0.02	-140.7	217.8
support in agriculture	(121.3)	(0.07)	(171.43)	(181.18)
Total land cultivated (ha)	52.93	-0.003	548.7	-81.8
	(88.58)	(0.04)	(339.89)	(53.33)
Self-perceived credit constraint	804.5***	-0.27*	1125.3***	693.4**
dummy (yes=1)	(224.7)	(0.14)	(364.72)	(322.37)
Season 2013-14 dummy (base= *boro*	-97.8***	-0.01	-62.0	-131.8***
season 2012-13	(31.3)	(0.01)	(47.17)	(39.93)
Division dummies (base= Barishal division)				
Dhaka division dummy (yes=1)	-751.9***	0.33	-724.9**	-1336.5***
	(235.7)	(0.21)	(348.50)	(327.77)
Khulna division dummy (yes=1)	343.5	0.51**	642.4	-682.5
	(349.8)	(0.21)	(645.42)	(562.04)
Rangpur division dummy (yes=1)	-107.8	0.66***	325.3	-1276.5***
	(252.9)	(0.21)	(509.52)	(483.80)
Dummy for the household that relied	-199.6			
on traders' advice for pesticides	(220.2)			
application (yes=1)				
Cumulative paved/gravel road (km.)	58.4***	0.048***		

at the sampled village	(18.9)	(0.02)		
A dummy for purchased pesticides on	-376.7	-0.21		
credit (yes=1)	(231.3)	(0.13)		
No. of markets within 5-km radius of	-71.6 (44.4)	-0.25***		
the sampled village		(0.06)		
Constant	1427.8**	-0.003	1590.9	3191.1***
	(643.5)	(0.57)	(973.72)	(1217.28)
lns1		7.79***		
		(0.20)		
lns2		7.76***		
		(0.01)		
r1		-0.75		
		(0.68)		
r2		0.082		
		(0.18)		
Sigma-u/Sigma_1	2204.87	2405.7***		
		(483.4)		
sigma_e /Sigma_2	427.17	2357.10***		
		(18.8)		
Rho/Rho_1	0.96	-0.64*		
		(0.40)		
Rho_2		0.08		
		(0.18)		
No. of observations	758	758		
Wald Chi 2 (10)	49.57	47.3		
Prob>Chi2	0.00	0.00		
Log likelihood		-7385.1		
Likelihood ratio test of independence				
of three equations				
Chi2 (1)		31.0		
Prob>Chi2		0.00		

Numbers in parentheses are standard errors calculated based on robust standard errors clustered at household level. *Significant at the 10% level, ** Significant at the 5% level and ***Significant at the 1% level.

Table 7: Average expected expenditure on pesticides per ha; treatment and heterogeneity effects based on the sources of information households relied on

All sample		To rely on trader (regime 1)	To rely on others (regime 2)	
Predicted probability		0.54	0.46	
Unconditional linear predicted expenditure on pesticides (BDT/ha)		3,783.5	2,896.8	
Sub samples		To rely on trader (regime 1)	To rely on others (regime 2)	Treatment effects
Farm households that relied on traders' suggestion	Yes (regime 1)	(a)2,664.6	(c) 3023.4	ATT= -358.8*** (-5.83)
Farm households that relied on other than traders' suggestion	No (regime 2)	(d) 5,088.0	(b) 2749.9	ATU=2338.1*** (46.9)
Heterogeneity effects	Base heterogeneities =	-2,423.4	237.5	Transition heterogeneity= -2149.9

Source: authors' calculation from ESR estimation in Table 7.