Journal of Agricultural and Resource Economics 40(3):1–18 ISSN 1068-5502

Do Pesticide Sellers Make Farmers Sick? Health, Information, and Adoption of Technology in Bangladesh

Shamma Adeeb Alam and Hendrik Wolff

We study the impact of supply-side and demand-side pesticide regulations on the adoption of health technologies and health outcomes in Bangladesh. We use a unique dataset that spans the chain from where farmers obtain information and which precautionary tools (i.e., masks, gloves) they use to subsequent health outcomes after spraying. In contrast to previous studies, we find that information from pesticide sellers increases the adoption of precautionary tools and subsequently improves health outcomes. We also find that there is substantial social learning from peers that act as key knowledge multipliers.

Key words: Bangladesh, health, information sources, peer network, pesticide, pesticide sellers, technology adoption

Introduction

Modern agriculture depends heavily on pesticide use, which has successfully increased productivity but also led to increasing concerns regarding farmers' health (Zilberman et al., 1991; Antle and Pingali, 1994). Mishandling of pesticides continues to pose a serious health problem for farmers, especially in developing countries. Annually, 26 million cases of pesticide poisoning result in 220,000 deaths worldwide (Richter, 2002). In the United States alone, Pimentel (2005) estimates that the public health cost of pesticide use amounts to $1.1 billion per year. Furthermore, prolonged pesticide exposure can reduce labor productivity and cause serious long-term eye, dermal, cardiopulmonary, neurological, and gastrointestinal problems (Pingali, Marquez, and Palis, 1994). While pesticides play a major role in enhancing agricultural productivity, these statistics necessitate a better understanding of the determinants of pesticide exposure.[1]

Prior studies (Antle and Pingali, 1994; Crissman, Cole, and Carpio, 1994; Palis et al., 2006) find that the main cause of pesticide poisoning is ignorance about its dangers. In principle, the problem of pesticide exposure can be managed using two approaches, supply-side and demand-side regulations. On the supply side, profit-maximizing pesticide sellers can provide proper instructions and sell health-protection products (e.g., masks, gloves). On the demand side, subsidized field educational programs can try to raise awareness among farmers to increase their use of health technologies

Shamma Adeeb Alam is an assistant professor in the Department of International Studies at Dickinson College. Hendrik Wolff is an assistant professor in the Department of Economics at University of Washington–Seattle and an associate professor in the Department of Economics at Simon Fraser University.
This research is supported by grants from the Hewlett Foundation and the Institute of International Education. We thank the editor, Gregmar Galinato, two anonymous reviewers, Trudy Cameron, Rachel Heath, Fahad Khalil, Lan Shi, Jennifer Meredith, staff at the International Rice Research Institute (IRRI), and the Bangladesh Rural Advancement Committee (BRAC) for helpful comments. We thank the World Bank for making the data available. We also thank farmers and pesticide sellers for sharing their experience during our field interviews. Views and analyses in this paper are those of the authors and do not necessarily reflect the opinions of the World Bank, the Hewlett Foundation, or the Institute of International Education.
Review coordinated by Gregmar I. Galinato.

[1] Here we use "pesticide exposure" as a synonym for experiencing a negative health outcome as a result of pesticide application.

during pesticide applications. This study contributes to the debate on the relative effectiveness of demand- versus supply-side interventions that influence farmers to adopt health technologies.

In practice, demand-side interventions have dominated development projects. Local governments have partnered with international donor organizations and NGOs in major efforts to raise awareness of the proper handling of pesticides and to encourage the use of Integrated Pest Management (IPM) techniques (van den Berg and Jiggins, 2007; Dasgupta, Meisner, and Huq, 2007; Rejesus et al., 2009). The government of Bangladesh initiated several such projects (worth over $200 million) over the last two decades to train extension workers and farmers on IPM with the assistance of donor organizations (Department of Environment, 2007; Ministry of Foreign Affairs of Denmark, 2012). Despite these efforts, cases of pesticide exposure are on the rise in developing countries (Gunnell and Eddleston, 2003); our dataset shows that half of all farmers in Bangladesh suffer from pesticide exposure each year.

This paper examines the impact of supply-side and demand-side information on the adoption of health technologies, pesticide handling, and health outcomes using a detailed household-level dataset from Bangladesh. In Bangladesh, three major information sources disseminate pest prevention knowledge: pesticide sellers, government field extension workers, and social learning amongst peer farmers. This paper describes the role of each information source and tests the relative effectiveness on farmers' subjective risk assessment, adoption of precautionary behavior, and health outcomes.

First, it has been repeatedly hypothesized that pesticide sellers in developing countries may misguide farmers by convincing them to purchase excessive quantities of often more toxic pesticides that lead to severe health outcomes. This view is particularly prevalent within state and international agencies such as the UK Department of International Development (DFID), the World Health Organization (WHO), and the United Nations Food and Agriculture Organization (FAO) (Hainsworth and Eden-Green, 2000; Vapnek, Pagotto, and Kwoka, 2007; Aitio et al., 2006). However, this contradicts the idea that pesticide sellers—who also sell seeds and fertilizers—aim to maintain a long-run relationships with clients and not to mislead for short-term profits.

Despite numerous studies on health outcomes and regulation of pesticide use, we are aware of only one study, Lopes Soares and Firpo de Souza Porto (2009), that empirically investigates the relationship between information sources and farmers' health. Consistent with the hypothesis that vendors could misguide farmers, Soares and Porto find that advice from pesticide sellers significantly increased farmers' illness. However, a profit motive in itself may not automatically lead to greater pesticide use. In fact, Liu and Huang (2013) recently find that information from agricultural agents, whose income is tied to pesticide sales, actually leads to a decrease in pesticide use by farmers. The controversial role of pesticide sellers warrants further investigation. This paper studies the impact of sellers in the context of Bangladesh.

Second, farmers receive information from agricultural field extension workers (AFEWs). The Bangladesh Ministry of Agriculture trains extension workers to disseminate information on handling pesticides, to educate farmers on the need to wear protective equipment (such as masks, glasses, boots) while spraying, and to promote IPM techniques (Rahman, 2003; Ricker-Gilbert et al., 2008; Department of Environment, 2007). The government considers these programs to be a success (Rahman, 2003).[2] In this paper, we study whether the information provided by these governmental programs actually arrives at the farm level.

Third, farmers discuss pest management strategies with neighboring peers. A growing literature (Foster and Rosenzweig, 1995; Munshi, 2004; Conley and Udry, 2010) demonstrates that farmers learn about new technologies (e.g., new varieties of seeds and fertilizers) from the experience of their peers. Studies on the adoption of health technologies have been few and show non-uniform results on whether peers increase adoption. On the one hand, Dupas (2012) finds that individuals increase adoption of antimalarial bednets because of the influence of peers. In contrast, Kremer

[2] Although there has been no study in a developing country, Lichtenberg and Zimmerman (1999) find that U.S. farmers who believe extension services are important have a greater concern for pesticide exposure.

and Miguel (2007) find that the negative side effects of deworming lead households to discourage their social contacts from participating in similar deworming programs in Kenya. Similarly, farmers in Bangladesh also report discomfort from wearing full body protective equipment in a hot and humid climate as a reason for not using any protection. In this study, we add to this literature and present the first paper to examine whether social learning from peers influences the adoption of health technology in agriculture.

We make several contributions to the literature. This paper highlights the role played by three key information sources—peers, pesticide sellers, and agricultural extension workers—in influencing farmers. This paper presents the first empirical study that examines these primary sources of information to both adoption of health technology and actual health outcomes of farmers. Using the most detailed database currently known to be available household survey on the information flow of pesticide use, we find that farmers who report obtaining advice from the supply side—pesticide sellers—increasingly adopt precautionary tools (e.g., masks) and are less likely to become ill. These same farmers also show a heightened concern regarding the long-term cancer risk of pesticide exposure. Second, on the demand side, we do not find evidence that training from the governmental field extension has any measurable influence on illness or precautionary behavior on the average farmer. However, a subset of "educated" farmers is positively affected by training. Third, we make an interesting observation in terms of social learning. We find that the average peer has a negligible effect on farmers' behavior. However, the learning effect is strong when information is provided by educated, trained peers. While the fraction of trained peers is very small in these communities, trained peers serve as important social multipliers in the farmers' network.

Lastly, this study has important policy implications. First, we demonstrate the significance of the network of pesticide sellers as an information source for farmers. This suggests that sellers could be more actively used as a valuable policy instrument to disseminate information and protective equipment. Second, we suggest that the government of Bangladesh and international donors reevaluate the current policy program of extension services, as their information does not seem to arrive effectively at the typical farm level. Finally, we find that the very small fraction of educated, trained farmers has a particularly positive effect on peers, suggesting that more targeted training programs to social multipliers can be valuable to enhance the information flow.

Our study is based on cross-sectional household data, which theoretically hinders us from drawing inferences on causality if unobserved confounders are present. We overcome these empirical challenges in several ways. First, we believe that we have employed the most comprehensive survey data currently available, which allows us to carefully explore heterogeneity over a range of robustness checks. Second, we do not observe endogenous sorting into the first contact with pesticide sellers, as almost all farmers (98%) purchase pesticides themselves from local sellers. However, whether a farmer reports having obtained information from a particular information source can still be endogenous. Third, we condition our estimates on a wide set of the arguably most important characteristics that should be correlated with sorting.[3] Our point estimates remain robust to the inclusion or exclusion of this set of characteristics. If omitted variable bias were a problem, we would expect endogenous factors to be correlated with some of these observables. In sum, we argue that unobserved heterogeneity is not a first-order problem in the interpretation of our cross-sectional analysis.

Information Flows in Bangladesh

How does information about proper handling of pesticides reach farmers? Manufacturers and wholesale importers of pesticides are required by law to label pesticide containers with detailed information on the recommended dosage, precautionary measures needed while handling and

[3] Number of household members; per capita income; farm size; farm equipment value; household head's body mass index, smoking behavior, educational characteristics; and various versions of fixed effects.

spraying the pesticide, and the symptoms of pesticide poisoning (Ministry of Agriculture, 1985). Labels are typically written in the native language, Bengali. To empirically check whether these regulations are followed, the first author of this article observed and interviewed a selection of large-scale pesticide wholesale stores and pesticide sellers in rural areas and confirmed that—among the sampled villages—pesticide containers provide the required information.[4][5]

Case studies of Bangladesh indicate that farmers seek advice from pesticide sellers on pesticide selection and use (Robinson, Das, and Chancellor, 2007; Department of Environment, 2007).[6] In addition to pesticides, farmers also purchase seeds and fertilizers from these sellers, indicating that many farmers are in frequent contact with these sellers (Robinson, Das, and Chancellor, 2007). Farming is the main source of employment in rural Bangladesh, and there are typically many retailers selling pesticide, seeds, and fertilizers in a given village (Hainsworth and Eden-Green, 2000; Robinson, Das, and Chancellor, 2007). The presence of multiple pesticide sellers in each village leads to competition among the sellers (Hainsworth and Eden-Green, 2000; Robinson, Das, and Chancellor, 2007). Hence, sellers may have incentives to maintain long-run relationships with farmers for their own profit maximization (and not to intentionally misguide them for short-term gains, as has been hypothesized by Vapnek, Pagotto, and Kwoka, 2007; Aitio et al., 2006). Due to this conflict of interest, however, previous IPM training strategies and awareness programs typically excluded the network of pesticide sellers.

To assist farmers with agriculture and pesticide related issues, the government employs agricultural field extension workers (AFEWs), who advise farmers directly on productivity-enhancing techniques, adopting IPM, and discouraging pesticide use (Ricker-Gilbert et al., 2008; Department of Environment, 2007). AFEWs conduct regular farm visits and organize local training programs. However, as each AFEW is responsible for 1000–1200 farmers, AFEWs have been criticized for not being able to effectively reach all farmers in their area (Haque, 2012).[7] As there is a lack of monitoring of field performance, AFEWs may not always have the same strong incentives as pesticide sellers to maintain long-term relationships with farmers. While the literature on AFEWs is sparse, Robinson, Das, and Chancellor (2007) and Haque (2012) find that farmers criticize AFEWs for not performing in their area or being unavailable when farmers need help. In a qualitative study by Haque (2012), farmers complained that AFEWs are not adequately competent to provide technical advice.

Clearly, information in Bangladesh also flows via face-to-face conversations with peer farmers. In particular, Robinson, Das, and Chancellor (2007) and Ricker-Gilbert et al. (2008) note that in Bangladesh, which is very densely populated, farmers often discuss pest management techniques with neighboring farmers, making social learning from peers an important source of information.

Data

This paper uses the 2003 Bangladesh Pesticide Use Survey (BPUS) conducted by the World Bank. The survey interviewed 771 farmers in forty-one communities (subdistricts) across eleven districts where pesticide-intensive crops are produced. Farmers are randomly selected from within these

---

[4] Photographs displaying pesticide stores and pesticide containers are available upon request. Staff at the International Rice Research Institute (IRRI) and Bangladesh Rural Advancement Committee (BRAC) confirmed with us in interviews that pesticides sold in Bangladesh, even in remote rural communities, typically contain the required detailed labels.

[5] This practice is in stark contrast to the situation in some other developing countries. For example, Wolff (1999) and Wolff and Recke (2000) report that pesticides in Ghana are typically decanted at stores into much smaller containers, such as Coca Cola bottles, and hence the information on content and appropriate handling is lost.

[6] A survey by Dasgupta, Meisner, and Mamingi (2005) in seven Bangladesh districts finds that 72% of sellers have basic training in handling pesticides.

[7] An IPM pilot project on farmers in central Bangladesh in 1999 achieved "reductions of pesticide [use] of as much as 80%... within one season following training in IPM in Bangladesh" (Department of Environment, 2007). We are not aware of any more quantitative study that analyzes the effectiveness of the AFEW system in Bangladesh.

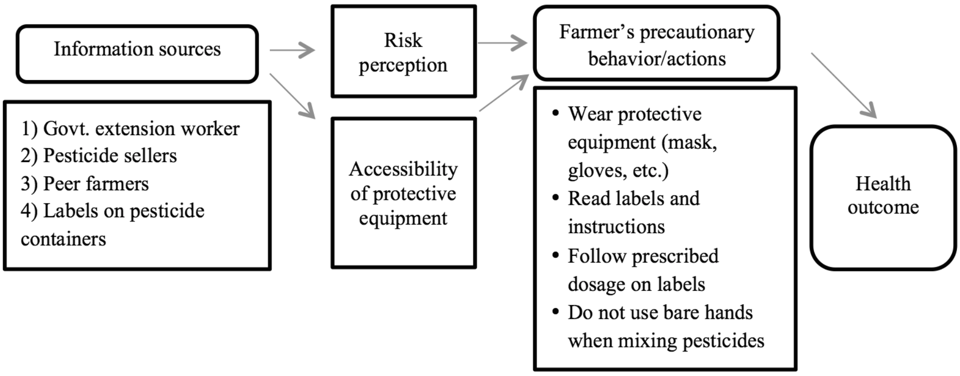

Figure 1. The Pathway through which Information Sources Affect Risk Perception, Precautionary Behavior, Use of Health Products and Health Outcomes

districts.[8] BPUS is unique in design, as it focuses on identifying the sources that inform farmers regarding many aspects of pesticide handling. In particular, detailed questions are asked with respect to information sources, farmers' perceptions of risk, pesticide use, precautionary behavior, and health symptoms experienced after pesticide applications. To our knowledge, information with this level of detail regarding pesticide use is not present in other surveys. All farmers apply pesticide themselves. Furthermore, 98% of farmers report that they purchase pesticides directly from pesticide sellers. This is an important feature of the dataset because it shows that potential endogenous sorting into the contact with pesticide sellers is only a concern for the 2% of farmers who do not purchase pesticides themselves.[9]

Figure 1 displays the pathway through which information sources affect health outcomes. The four main information sources that we identify from the survey are AFEWs, pesticide sellers, peer farmers, and labels on pesticide containers. How knowledge about handling pesticides is transformed into precautionary behavior, however, depends both on the information source as well as on the farmer's risk perception. According to our survey, precautionary measures can be grouped into categories: (i) using health products (i.e., wearing protective equipment while spraying and handling pesticides), (ii) reading labels and instructions on pesticide containers, (iii) following instructions and prescribed dosages indicated on the labels, and (iv) not using bare hands when mixing pesticides. Finally, accessibility and affordability of protective equipment and farmer-specific application practices determine health outcomes.

Information Source

The survey asks whether information regarding pesticides was obtained from the following three key sources:[10]

1. AFEWs,
2. pesticide sellers,
3. peer farmers.[11]

---

[8] See Dasgupta, Meisner, and Huq (2007) for a detailed description of the survey. Further details of the survey can also be obtained at: http://go.worldbank.org/KPANSWSYE0

[9] Appendix table A12 shows that our estimates are robust to the exclusion of farmers who do not purchase the pesticides themselves.

[10] Less than 0.5% of farmers report to have received information from NGOs. As this percentage is too small for further statistical analysis, we drop these observations from our estimations.

[11] In the survey, this category is labeled "other sources." Because this category mainly consists of neighboring farmers, friends, and family members, we refer to this category as "peer farmers."

Table 1. Sources by Information Channels (N=759)

	Precautionary Measures Are Necessary	Reading Label Is Necessary	Bare Hands Should Not be Used
		Section (i): Direct Information Channel	
Pesticide Seller	26.2%	45.6%	33.7%
Ministry AFEW	10.3%	5.8%	7.5%
Peer Farmer	43.6%	39.5%	42.8%
Total	**80.1%**	**90.9%**	**84.0%**
No Knowledge	19.9%	9.1%	16.0%
		Section (ii): Advisory Channel: Types of Trained Peers	
Pesticide Seller		7.25%	
Ministry AFEW		9.75%	
Peer Farmer		7.25%	
Total		**24.25%**	
No trained peer		75.75%	

Notes: Section (i) provides a breakdown of information sources provided through direct channels. Information sources are mutually exclusive to one another, as each farmer can provide only one answer. Section (ii) provides a breakdown of types of trained peers, which are also mutually exclusive.

These three sources can influence farmers through two channels: a direct channel and/or an advisory channel. A direct channel provides direct person-to-person information to farmers, while an advisory channel consists of trained personnel, possibly acting as an auxiliary source, from whom farmers can seek advice. For policy implications, it is important to identify whether the influence on health or behavior originates from the direct or the advisory channel.

Direct Channel

Farmers are first asked about the direct channel: "What is the main information source of the following instructions that you may have received:"

1. "While spraying pesticides, you should wear precautionary equipment (gloves, hat, mask, full sleeve shirt, full length trousers, and shoes)."
2. "You should read labels on the package and follow instructions (if you cannot read, please get help from others who can read)."
3. "You should not mix pesticide with bare hands"

Which sources of information are the most prevalent? Table 1 provides a breakdown of the fraction of farmers obtaining instructions from each of the three sources (1)–(3). Column 1 shows that 80.1% of farmers report that they have been informed that wearing protective equipment is necessary while spraying pesticides. Among these farmers, peer farmers represent the biggest fraction (43.6%), followed by pesticide sellers (26.2%) and AFEWs (10.3%). Subsequent columns in the table represent similar breakdowns for questions (2) and (3) by information source. While the table indicates that peer farmers and pesticide sellers are the most common information sources in Bangladesh, we later estimate the effectiveness of each information source in influencing farmers' behavior. Additionally, farmers can be influenced by indirect sources. We analyze this through the advisory channel.

Advisory Channel

In terms of training, 97% of the sample had not obtained any formal training on the handling of pesticides.[12] However, the survey asks each farmer whether he or she knows of any other person who can provide such training. We label these persons as "trained peers" of type AFEW, type pesticide seller, or type peer farmer. These trained peers represent the advisory channel. We examine whether these advisory sources influence farmers in a different way that will not otherwise be captured in our estimation. It is possible that the advisory source may be reinforcing the information that the farmer originally received from a direct channel and consequently affects farmers' risk perception and precautionary behavior. As shown in section (ii) of table 1, only 24% of farmers have trained peers. Among them, type AFEW (9.75%) is the most prevalent, followed by trained pesticide sellers (7.25%) and trained village peers (7.25%).[13]

Precautionary Behavior

Does knowledge translate into changes in precautionary behavior? Following the knowledge questions (1)–(3) on information sources, the survey asks follow-up questions about farmers' actual application practices:

1# Do you use Personal Protective Equipment (PPEs) during pesticide application?

- 1#a Mask;
- 1#b Gloves;
- 1#c Boots;
- 1#d Hats;
- 1#e Glasses;

2# Do you read labels on pesticide packages?

- 2#a Do you follow instructions and the prescribed dose mentioned on the label?
- 2#b Do you read instruction on flyers that come with purchased pesticide describing safety issues or procedures?
- 2#c Do you seek assistance if you are unable to read the labels?

3# Do you use bare hands to mix pesticide?

Table 2 displays the percentage of farmers that respond to the information received (1)–(3) with precautionary actions (1#)–(3#). We find that most farmers do not follow through with precautionary action. Although 81% of farmers are aware that wearing protection is required, only 14% actually use PPEs. Similarly, although 91% of farmers are informed that reading labels is important, only 58% of these informed farmers actually read labels, 46% follow the instructions on labels, and 28% follow the prescribed dose. We see a similar pattern for all other precautionary behaviors. This lack of implementation could arise because farmers may not find certain sources of information credible. In our regression analysis below we aim to identify those sources that actually have an influence on farmers' precautionary behavior and ultimately health outcomes.

A second set of follow up questions—for those that do not wear PPEs—asks for the barriers to PPE adoption. Responses are displayed in table 3. The majority of sampled farmers deemed four of the five PPEs to be unnecessary: mask (54%), gloves (52%), hats (56%), and glasses (55%). Lack of availability[14] and discomfort while wearing the PPEs in the hot tropical climate are the second

[12] Training is typically provided by AFEWs in agricultural field education extension programs on pesticide use.

[13] Unfortunately, the data do not track whether the trained village peers obtained the original training from AFEWs, pesticide sellers, or both.

[14] We find that a lack of financial resources does not explain the low adoption rate of PPEs. We do not find a correlation between income or education and the lack of PPE availability.

Table 2. Farmers' Knowledge versus Precautionary Behavior: Do Farmers Follow Knowledge with Actions? (N=759)

	N	Percentage
Knowledge: Read the labels on the pesticide container	691	
of them, how many read labels	399	58%
of them, how many follows the instruction on labels	315	46%
of them, how many follows prescribed dose	195	28%
Knowledge: Precaution and protection is needed	611	
of them, how many use any protection	85	14%
of them, how many use mask	45	7%
of them, how many use gloves	11	2%
of them, how many use hats	37	6%
of them, how many use glasses	23	4%
of them, how many use boots	8	1%
Knowledge: Do not mix pesticide with bare hands	640	
of them, how many do not use bare hand	292	46%
When purchasing pesticide, are you supplied with info in fliers?	593	
of them, how many reads and understand	368	62%

Table 3. Percentage of Farmers Citing Different Reasons for Not Adopting PPEs

Protections	Use	Unnecessary	Unavailable	Uncomfortable
Mask	7%	54%	31%	13%
Hat/Head Cover	6%	56%	22%	18%
Glasses	3%	55%	24%	13%
Gloves	2%	52%	26%	19%
Boots/Shoes	1%	34%	14%	45%

Notes: Only farmers who do not use certain Personal Protective Equipment (PPE) are asked about the reason for not using that PPE. The three set of responses: "Unnecessary," "Unavailable," and "Uncomfortable" are mutually exclusive, as farmers can choose only one response.

and third most cited reasons why PPEs are not adopted. Since the survey also details the pesticides used by each farmer during the past twelve months, we can compare these answers with the WHO toxicity standards of the listed pesticides (World Health Organization, 2010). We find that in the last year, 94% of the sample used at least one highly toxic (according to the WHO toxicity standard) pesticide, which can cause severe health effects if PPEs are not adequately used during application.

Risk Perception

To quantify the level of subjective perceived risk, the survey asks about the perceived long-term effects of pesticide use: "Do you think that pesticide use and/or exposure, overall, has any negative long-term impacts on health, such as cancer?" Answers are on a scale from 1 to 5: "no effect" (1), "small effect" (2), "medium effect" (3), "large effect" (4), and "fatal effect" (5). Figure 2 shows that 43% reported that they believed pesticide use and exposure to have no or small effect, while only 1% reported it having a fatal effect. These results are disconcerting, as 94% of the sample uses highly toxic pesticides. This difference in actual versus perceived toxicity risk indicates an important knowledge gap among most farmers.

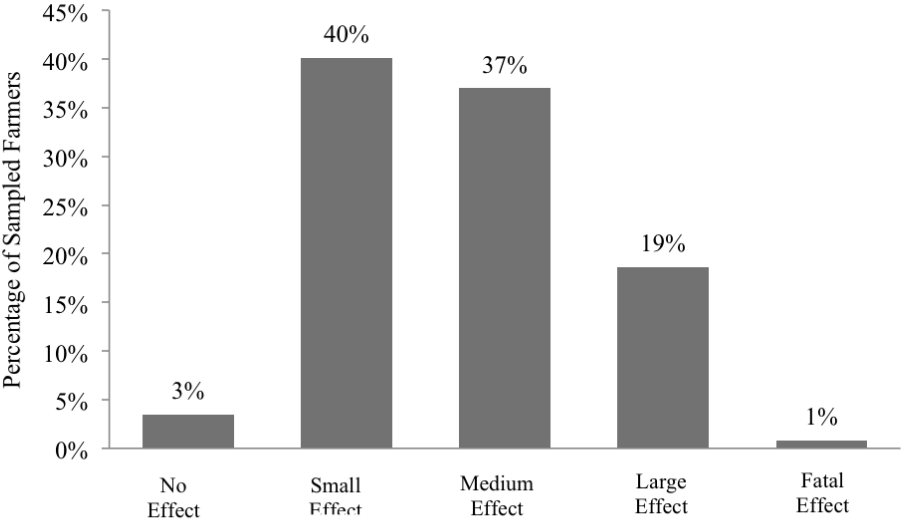

Figure 2. Perceived Long-Term Effects of Pesticide Exposure for the Sampled Farmerse

Health Outcome

In our regression analysis, the health outcome of farmers is our main variable of interest. The survey asks if within the past year prior to the date of the interview the farmer experienced one of several symptoms after spraying pesticides—eye irritation, headache, vomiting, dizziness, diarrhea, fever, convulsions, skin irritation, or shortness of breath.[15] If a respondent has felt one or more of the listed symptoms we code the health outcome dummy as 1 and as 0 otherwise.[16] Under-reporting of the true pesticide exposure occurs if symptoms are not visible immediately or built up over longer-term exposures only from repeated spraying.

Estimation Strategy and Summary Statistics

We examine the effect of information sources on risk perception, precautionary behavior, and health outcomes from pesticide exposure. The following simple theoretical framework guides us in developing our econometric specification. Following figure 1, information source affects risk perception, risk perception affects precautionary behavior, and precautionary behavior affects health. Hence, we model health as a recursive system of these prior input variables as

$$\text{(1)} \quad \textit{Risk Perception}_{ij} = f(\textit{Information Source}_k, X_{ij}, A_{ij}, \mu_j),$$

$$\text{(2)} \quad \textit{Precautionary Behavior}_{ij} = h(\textit{Risk Perception}_{ij}, X_{ij}, A_{ij}, \mu_j),$$

$$\text{(3)} \quad \textit{Health}_{ij} = g(\textit{Precautionary Behavior}_{ij}, X_{ij}, A_{ij}, \mu_j),$$

where f, g, and h represent three different functional forms and subscripts i, j, k represent individual, location, and information source, respectively; A_{ij} includes other information related variables and X represents farmer characteristics.

However, as precautionary behavior is a function of risk perception, we can rewrite our precautionary behavior variable as a function of information source directly by substituting equation (1) into equation (2), such that

$$\text{(4)} \quad \textit{Precautionary Behavior}_{ij} = \tilde{h}(\textit{Information Source}_k, X_{ij}, A_{ij}, \mu_j).$$

[15] Symptoms of toxic pesticides are typically visible within a few hours (World Resources Institute et al., 1998; Dasgupta, Meisner, and Huq, 2007).

[16] 85% of the farmers report that they are “very” or “extremely” sure that pesticide exposure caused those symptoms.

Similarly, we can rewrite health as a function of information source directly by substituting equation (4) into equation (3), such that

$$(5) \qquad Health_{ij} = \tilde{g}(Information\ Source_k, X_{ij}, A_{ij}, {}_j).$$

Econometrically, equation (5) has two advantages. First, in the health equation we do not need to model the endogenous nature of precautionary behavior and risk perception. It also has the advantage that we avoid the problem of multicollinearity among information source, risk perception, and precautionary behavior. Finally, as the three outcome variables risk perception, precautionary behavior, and health are correlated within each household. We also model the within-farmer correlation structure of equations (1), (4), and (5) with a SUR model as a robustness check and find qualitatively similar results. The results are presented in appendix tables A14 and A15.

We estimate equations (1), (4), and (5) employing the following regression equation:

$$(6) \qquad Y_{ij} = \sum_c \sum_k \beta_{1k} I_k C_c + \beta_2 X_{ij} + \beta_3 A_{ij} + \mu_j + \varepsilon_{ij},$$

where Y_{ij} represents alternatively an indicator for risk perception, precautionary behavior, or the dummy variable for illness of individual i in subdistrict j and I_k is a set of dummy variables indicating the kth information source, where $k \in \{(A),(B),(C)\}$ and C_c represent whether the information was obtained via the direct or the advisory channel indexed by c. Additionally, A_{ij} includes information-related variables such as instructions on labels or fliers. Farmer characteristics of age, education, body mass index (BMI), farm size, household income, and value of farming equipment are represented by X_{ij}. As smoking is known to aggravate symptoms of pesticide exposure such as pulmonary problems (Pingali, Marquez, and Palis, 1994), we also include a dummy variable for smoking. Lastly, μ_j indexes the subdistrict-level fixed effects.[17] We cluster standard errors at the district level to allow for spatial correlation across farmers in the same jurisdiction.

Prior to moving on to our estimation results, it is useful to note potential limitations in the interpretation of results. An important caveat in our analysis is that it is based on cross-sectional data, which theoretically hinders us from drawing strict inferences on causality as we are unable to control for unobserved farmer heterogeneity. Hence our estimations may suffer from endogeneity biases. We believe, however, that this problem is not of first-order concern in our dataset. First, we do not observe endogenous sorting into contact with pesticide sellers, as almost all farmers (98%) purchase pesticides themselves. Second, we condition our estimates on a wide set of arguably the most important characteristics that should be correlated with sorting. To this end, table 4 displays summary statistics and p-values comparing characteristics of ill farmers to non-ill farmers. Ill farmers tend to be significantly younger and use more pesticides than non-ill farmers. In our following regressions, we therefore control for these individual and household characteristics. In particular, the following—arguably most important—variables (that potentially could concern endogenous sorting) do not show statistically significant differences: number of household members, per capita income, farm size, farm equipment value, household head's BMI, smoking behavior, and education.

Finally, we explore whether farmers sort into different information sources depending on their observable characteristics.[18] If a particular farmer characteristic predicts receiving information from a certain source, it may suggest that endogenous sorting is associated with that characteristic. Appendix table A13 presents the results. We find that characteristics such as income, farm size, farm equipment value, age, and farmer education (until secondary education) do not determine whether the farmer receives information from a certain source. This suggests that endogenous sorting is not associated with these characteristics. However, we find that farmers who have completed secondary

[17] The 2003 BPUS survey took place in thirty-one subdistricts of eleven districts in Bangladesh. Subdistricts are jurisdictions that often have their own legislative procedures. To account for potential differences, we control for the subdistrict fixed effect and (due to spatial correlation) cluster the error term, ε_{ij}, by district.

[18] We thank one referee for suggesting this specification test.

Table 4. Summary Statistics of Farmer Characteristics (N=759)

	Ill		Not Ill		
Number	364		395		
Percentage	48%		52%		
Farmer Characteristics	**Mean**	**St Dev**	**Mean**	**St Dev**	**p-values**
Number of Household Members	6.3	(3.0)	6.1	(2.9)	**0**.27
Farm Size (in Acres)	1.5	(1.5)	1.4	(1.4)	0.28
Yearly HH Per Capita Income	17,337	(12,956)	15916	(14,363)	0.17
Farm Equipment Value	5,591	(10,262)	5531	(11,959)	0.94
Age	34	(10.99)	36	(11.29)	0.026**
Education					
No Education	34%	(0.47)	42%	(0.49)	0.024**
Below Primary	26%	(0.44)	24%	(0.43)	0.53
Primary & Above	27%	(0.44)	23%	(0.42)	0.27
Secondary & Above	12%	(0.32)	11%	(0.31)	0.61
Body Mass Index (BMI)	19.7	(2.24)	19.5	(2.07)	0.3
Smoke Cigarette	56%	(0.50)	58%	(0.49)	0.45
Pesticide Quantity, Solid (in Kg)	5.9	(8.30)	4.5	(6.74)	0.012**
Pesticide Quantity, Liquid (in Liters)	4.5	10.5	2.2	5.5	0.00***

Notes: p-values in the last column compare the mean of characteristics of sick farmers to non-sick farmers. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. In the dataset, farm sizes are enumerated in seven distinct bins of farm areas. We approximate farm size by assuming the midpoint of each bin.

or higher levels of education are more likely to receive information from their peers and less likely to receive information from pesticide sellers compared to farmers with no education. This suggests some level of sorting within this highest education bracket. However, this sorting would apply to only the 6% of farmers who have finished a secondary level of education and obtained information from peers and to only the 1.3% of farmers who received the highest level of education and also obtained information from pesticide sellers. To check whether these relatively small fractions of farmers drive a selection bias, we conduct a robustness check by dropping the farmers with the highest level of education from the sample and examine the effect on our coefficients of interest. We find that dropping the farmers with the highest level of education does not qualitatively change our main parameters of interest.[19]

Results and Discussion

The regression results follow the chart in figure 1 from left to right. Do any of the information sources (1)–(3) influence farmers' risk perception, precautionary behavior, or health outcomes? Table 5 displays the effect of information sources on the perceived long-term health effects of pesticide using ordinary least squares (OLS).[20] In columns 1 to 3, we first aggregate the direct channel and the advisory channel into the three key sources of information: pesticide sellers, AFEWs, and peer farmers. We find that information from sellers significantly increases farmers' risk perception, compared to farmers with no information, after controlling for district fixed effects (column 1), subdistrict fixed effects (column 2), or farmer characteristics (column 3). Overall, adding these additional regressors slightly lowers the magnitude of the coefficients. To be conservative, we control for the subdistrict fixed effects and these individual characteristics in all further estimations.

[19] Results are available on request.

[20] We use the responses to question (1), "What is the main information source of the following instructions that you may have received: While spraying pesticides, you should wear precautionary equipment," as our key information source variable.

Table 5. Effect of Information Sources on Farmer's Perceived Long-Term Effects (N=717)

	Dependent Variable: Farmer's Perceived Long-Term Effects					
	Specification: OLS					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Pesticide Seller (Aggregate)	0.203*	0.191*	0.176*			
	(0.111)	(0.100)	(0.097)			
Extension Worker (Aggregate)	0.159	0.108	0.065			
	(0.107)	(0.112)	(0.118)			
Peer Farmer (Aggregate)	0.204	0.154	0.137			
	(0.118)	(0.109)	(0.113)			
Per Capita Income			0.003	0.004	0.003	0.004
			(0.003)	(0.003)	(0.003)	(0.002)
Value of Equipment			0.003	0.003	0.003	0.003
			(0.003)	(0.003)	(0.003)	(0.003)
Age			−0.006	−0.006	−0.006	−0.006
			(0.004)	(0.004)	(0.004)	(0.004)
Education						
Primary (1–5 years)			0.071	0.075	0.074	0.088
			(0.061)	(0.060)	(0.061)	(0.064)
Junior High (6–10 years)			0.009	0.011	0.009	0.016
			(0.070)	(0.067)	(0.070)	(0.092)
Secondary (11+ years)			0.114	0.122	0.115	0.116
			(0.152)	(0.155)	(0.162)	(0.128)
Direct Channel						
Pesticide Seller			0.209***	0.232***	0.228***	
				(0.045)	(0.065)	(0.063)
AFEW				0.089	0.113	0.113
				(0.163)	(0.175)	(0.183)
Peer Farmer			0.159	0.181	0.162	
				(0.104)	(0.119)	(0.131)
Advisory Channel						
Pesticide Seller				0.082	0.083	
					(0.216)	(0.220)
AFEW					0.036	0.037
					(0.095)	(0.097)
Peer Farmer				0.074	0.074	
					(0.148)	(0.130)
Follow Instructions on Labels						0.213***
						(0.052)
Understand Instructions on Fliers					−0.047	
						(0.099)
District Fixed Effects	Yes	No	No	No	No	No
Subdistrict Fixed Effects	No	Yes	Yes	Yes	Yes	Yes
R^2	0.067	0.106	0.128	0.130	0.131	0.145

Notes: Standard errors are in parentheses. Standard errors are computed after correcting for heteroskedasticity and correlation within district clusters. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. The regressions in columns 3–6 further control for farm size, quantity of pesticide used, BMI, and smoking dummy.

Our point estimate of interest, pesticide sellers, remains robust to the inclusion or exclusion of farmers' individual characteristics: age, education, income, value of farming equipment, quantity of pesticide used, and spatial fixed effects (columns 2 and 3). This set of control variables arguably includes the most important factors behind farmer precautionary behavior and is hence likely correlated with any missing variables that could explain further unobserved heterogeneity. This robustness suggests that this form of endogeneity is unlikely to be a major concern in our data. In all following regressions, the inclusion or exclusion of this set of additional regressors (or including independent variables one by one) never qualitatively affects our point estimates of interest. This provides suggestive evidence that endogenous sorting should not be of first-order concern. These additional robustness checks are provided in appendix tables A1–A11.

Next we disaggregate the information sources into the direct channel and the advisory channel.[21] Column 4 shows that pesticide sellers have a significant effect through the direct channel, and column 5 shows that the sellers continue to have a significant effect when controlling for the types of trained peers in the advisory channel. The coefficients of information sources in the direct channel remain robust, even after adding the variables representing advisory channel. This robustness suggests that multicollinearity between direct and advisory channels is not a concern for our estimates. Finally, one can argue that labels on pesticide containers (as required by Ministry of Agriculture, 1985) themselves represent an information source. Controlling for this in column 6,[22] we find no qualitative difference in the main estimates of interest (the parameter of pesticide sellers changes slightly from 0.232 to 0.228). Finally, we find that peer farmers and AFEWs have no significant effect for any of these specifications.

Do information sources differentially impact the adoption of health protection products? Table 6 shows the impact of information sources (1)–(3) on the likelihood of using any of the three most important PPEs: gloves, masks, and boots. Column 1 shows that pesticide sellers and peer farmers increase the likelihood of farmers' adopting PPEs compared to farmers who receive no information. The effect persists when we control for reading instructions on pesticide containers (column 2). Disaggregating the sources by channel in column 3, we again find that pesticide sellers as a direct channel significantly increase farmers' PPE adoption. As a robustness check, we add glasses (column 4) and hats (column 5) to the list of PPEs and find that sellers maintain the significant effect, although the effect for peer farmers disappears.[23]

In table 7 we continue the analysis of the impact of information sources (1)–(3) on precautionary behavior.[24] Column 1 shows that all three sources significantly increase the likelihood of reading labels or seeking assistance if unable to read. We find a similar effect when disaggregating the sources in column 2. However, when we examine the influence of these sources on farmers actually following the instructions on labels (columns 3 and 4) or applying the prescribed dose (columns 5 and 6), we find that only pesticide sellers (both on the aggregate and also as the direct and advisory channel) significantly increase the likelihood of following those precautionary actions. In contrast, peer farmers and AFEWs do not have such consistent significant effects. Finally, in column 7, (using responses to question 3) we again find that pesticide sellers as a direct channel significantly increase the likelihood of not using bare hands to mix pesticides.

---

[21] In some cases farmers list the same source as both the direct and the advisory information source. As a robustness check, we test alternative coding schemes. For those farmers who report obtaining the same information from both the direct and the advisory channel, the coding can be either as advisory channel only, direct channel only, or a separate variable for these special cases of multiple sources. In all of these robustness tests, we find that our main results are unaffected in these alternative categorization schemes.

[22] The specific variables used are "follow instructions on label" and "understanding instructions on flyer."

[23] For the interpretation of these results, note that although technically inadequate, farmers can wear reading glasses or religious caps as protective equipment. Our data do not allow us to distinguish between protective glasses and reading glasses or between religious caps and protective hats.

[24] Table 7 displays the marginal probability effects of the probit estimation. The information variable informs the farmer of the necessity of reading labels (i.e., the response to question (2) quoted in the data section).

Table 6. Influence of Information Sources on Use of Farmers' Personal Protective Equipment (N=757)

	Mask, Gloves or Boots	Mask, Gloves or Boots	Mask, Gloves or Boots	Mask, Gloves, Boots or Glasses	Mask, Gloves, Boots, Glasses or Hats
	Specification: OLS				
Dependent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Pesticide Seller (Aggregate)	0.057**	0.056**			
	(0.021)	(0.020)			
Extension Worker (Aggregate)	0.016	0.015			
	(0.022)	(0.022)			
Peer Farmer (Aggregate)	0.025**	0.020*			
	(0.011)	(0.009)			
Direct Channel					
Pesticide Seller		0.049**	0.042**	0.046**	
			(0.020)	(0.015)	(0.019)
AFEW			−0.009	0.024	0.019
			(0.042)	(0.024)	(0.023)
Peer Farmer			0.004	0.005	0.000
			(0.011)	(0.013)	(0.013)
Advisory Channel					
Pesticide Seller		0.050	0.033	−0.009	
			(0.051)	(0.054)	(0.063)
AFEW			0.030	0.005	−0.015
			(0.040)	(0.031)	(0.030)
Peer Farmer		0.062*	0.042	0.042	
			(0.031)	(0.033)	(0.042)
Follow Instructions on Labels		0.049**	0.050**	0.075***	0.093***
		(0.019)	(0.019)	(0.021)	(0.022)
Understand Instructions on Fliers		0.022	0.019	−0.001	−0.002
		(0.035)	(0.034)	(0.037)	(0.031)
R^2	0.153	0.161	0.164	0.188	0.201

Notes: Standard errors are in parentheses. Standard errors are computed after correcting for correlation and heteroskedasticity within district clusters. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. All regressions further include farm size, per capita income, equipment, education, age, quantity of pesticide used, BMI, smoking dummy, and subdistrict fixed effects as additional regressors.

To summarize, we consistently find that pesticide sellers improve farmers' risk perception and precautionary behavior. However, does this also translate into improved health outcomes? Table 8 reports probit marginal probability effects of information sources (1)–(3) on illness.[25] In column 1 we find that pesticide seller and peer farmers significantly reduce the likelihood of illness. In columns 2 and 3, we disaggregate sources by channel and again find that sellers as a direct channel significantly decrease the likelihood of illness. Sellers continue to remain significant when we control for instructions on labels and fliers (column 4) as well as the specific instruction that it is dangerous to mix pesticide using bare hands (column 5). In all of the specifications we find that the average peer has a positive but negligible effect on other farmers' health. However, the social learning effect is particularly strong among the very small fraction of the more educated, trained peers, who serve as important social multipliers in the farmers' network.

[25] To code this, in table 8 we use the responses with respect to question (1) quoted in the data section.

Table 7. Influence of Information Sources on Use of Farmers' Precautionary Behavior Using Probit Specification

	Read Label or Seek Assistance if Unable to Read Labels		Follow Instructions on Label		Follow Prescribed Dose as Indicated on Label		Hands Not Used for Mixing Pesticide
Dependent Variable	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**
Pesticide Seller (Aggregate)	0.089***		0.113**		0.180***		
	(0.025)		(0.052)		(0.053)		
Extension Worker (Aggregate)	0.045**		0.084		0.180*		
	(0.018)		(0.116)		(0.101)		
Peer Farmer (Aggregate)	0.108***		0.138		0.162***		
	(0.036)		(0.102)		(0.062)		
Direct Channel							
Pesticide Seller		0.085***		0.159**		0.114*	0.194***
		(0.027)		(0.062)		(0.063)	(0.063)
AFEW		0.045**		0.215		0.149	0.143
		(0.022)		(0.165)		(0.139)	(0.091)
Peer Farmer		0.110***		0.201**		0.082	0.150*
		(0.026)		(0.098)		(0.061)	(0.078)
Advisory Channel							
Pesticide Seller		0.063***		0.159**		0.317***	0.171
		(0.009)		(0.075)		(0.088)	(0.117)
AFEW		0.039		0.040		0.202**	0.238***
		(0.024)		(0.116)		(0.101)	(0.053)
Peer Farmer		0.047*		0.083		0.328***	0.178***
		(0.028)		(0.127)		(0.116)	(0.049)
N	743	743	744	744	746	746	749
R^2	0.21	0.22	0.09	0.09	0.13	0.14	0.11

Notes: The table presents marginal probability effects of the probit estimation and estimated standard errors (in parentheses).Standard errors are computed after correcting for heteroskedasticity and correlation within district clusters. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. All regressions further include farm size, per capita income, education, age, value of farm equipment, BMI, smoking dummy, quantity of pesticides used, and subdistrict fixed effects as additional regressors.

In summary, our regression results in tables 5 to 8 suggest that advice from pesticide sellers consistently leads to enhanced risk perception, adoption of health products and precautionary actions, and reduced likelihood of illness. These results are significant and in contrast to the notion presented in previous literature that sellers misguide farmers. We also find that trained peer farmers (advisory channel) have a positive effect on precautionary measures and health outcomes but that peers in the direct channel (who are likely untrained) do not have any effect. This underlines that formal training has positive spillover effects on neighboring peers. It is remarkable that such small fraction of trained peer farmers (7.25%) provides significant results, whereas we cannot find a significant effect on risk perception, precautionary measures, or health for the 10.3% of AFEWs.[26]

Conclusions

Our study has important policy implications. We show that pesticide sellers may be playing a crucial role in disseminating information that improves health in developing countries. Therefore, in future regulations, governments may want to consider using the network of pesticide sellers

[26] The only exception is column 7 of table 7 (where AFEWs have a positive effect on the instruction that farmers must not use bare hands when mixing pesticides).

Table 8. Impact of Information Sources on Illness (N=748)

	Specification: Probit				
Dependent Variable: Illness	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
Pesticide Seller (Aggregate)	-0.177^{***}				
	(0.053)				
Extension Worker (Aggregate)	−0.051				
	(0.057)				
Peer Farmer (Aggregate)	-0.163^{**}				
	(0.067)				
Direct Channel					
Pesticide Seller		-0.122^{**}	-0.179^{***}	-0.182^{***}	-0.183^{***}
		(0.061)	(0.068)	(0.070)	(0.070)
AFEW		0.005	−0.053	−0.053	−0.075
		(0.106)	(0.117)	(0.112)	(0.131)
Peer Farmer		−0.087	-0.149^{*}	−0.143	−0.148
		(0.084)	(0.089)	(0.088)	(0.095)
Advisory Channel					
Pesticide Seller			-0.156^{***}	-0.155^{***}	-0.151^{***}
			(0.059)	(0.059)	(0.056)
AFEW			−0.049	−0.044	−0.041
			(0.039)	(0.035)	(0.033)
Peer Farmer			-0.235^{***}	-0.228^{***}	-0.224^{***}
			(0.053)	(0.052)	(0.050)
Follow Instructions on Labels				−0.065	−0.066
				(0.040)	(0.041)
Understand Instructions on Fliers				−0.079	−0.080
				(0.053)	(0.052)
Not Use Hand					
Pesticide Seller					0.007
					(0.034)
AFEW					0.044
					(0.130)
Peer Farmer					0.015
					(0.060)
R^2	0.09	0.09	0.09	0.1	0.1

Notes: The table presents marginal probability effects of the probit estimation estimated standard errors (in parentheses). Standard errors are computed after correcting for heteroskedasticity and correlation within district clusters. Single, double, and triple asterisks (*, **, ***) indicate significance at the 10%, 5%, and 1% level. All regression further include farm size, farm equipment value, per capita income, education, age, BMI, smoking dummy, quantity of pesticide used and subdistrict fixed effects as additional regressors.

present in rural areas, which are often difficult to reach via the extension workers. According to our results, sellers raise awareness and are already present in all relevant agricultural rural areas. Over 50% of farmers report that they do not have access to masks or gloves. Therefore, supply-side regulations can consider selling protective equipment through the network of pesticide sellers. Sellers would always be willing to market and sell protective equipment as long as it increases their profits. Other countries have used similar strategies. The Chinese government hired extension agents, whose incomes are tied to the sale of pesticide, to educate farmers in order to decrease pesticide use (Liu and Huang, 2013). We argue that a similar strategy may work in the context of Bangladesh, where the government could use the network of pesticide sellers to market and sell PPEs to farmers. For example, a required bundling policy of sales of protective equipment together with pesticides (e.g., one mask per container) could increase awareness and use of protective equipment. Our results further suggest that the government should reexamine its demand-side strategies by which extension workers are used to disseminate information. We do not find that AFEWs having any significant influence on farmers. Finally, we find that the very small fraction of trained farmers have a particularly positive effect on peers, suggesting that more targeted training programs to social multipliers could be valuable for enhancing information flow.

[Received May 2014; final revision received July 2015.]

References

Aitio, A., A. Arlt, R. Awang, M. Balali-Mood, N. Besbelli, S. Cali, G. Calvert, N. Chaudhuri, B. Dinham, A. Dawson, G. Ekstroem, L. Fruchtengarten, A. Fait, P. Jambulingam, C. Jong-Boon, D. Kelili, L. London, D. Lunn, G. Manuweera, G. Matthews, B. Murray, I. Makalinao, A. Sunden-Bylehn, M. Tiramani, W. Temple, B. Watson, J. Williams, and M. Zaim. *Sound Management of Pesticides and Diagnosis and Treatment of Pesticide Poisoning: A Resource Tool*. Geneva: Joint publication by the United Nations Environment Programme (UNEP) and the World Health Organization (WHO) International Programme on Chemical Safety (IPCS) Pesticide Evaluation Scheme, 2006.

Antle, J. M., and P. L. Pingali. "Pesticides, Productivity, and Farmer Health: A Philippine Case Study." *American Journal of Agricultural Economics* 76(1994):418–430.

Conley, T. G., and C. R. Udry. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review* 100(2010):35–69.

Crissman, C. C., D. C. Cole, and F. Carpio. "Pesticide Use and Farm Worker Health in Ecuadorian Potato Production." *American Journal of Agricultural Economics* 76(1994):593–597.

Dasgupta, S., C. Meisner, and M. Huq. "A Pinch or a Pint? Evidence of Pesticide Overuse in Bangladesh." *Journal of Agricultural Economics* 58(2007):91–114.

Dasgupta, S., C. Meisner, and N. Mamingi. "Pesticide Traders' Perception Of Health Risks : Evidence From Bangladesh." Policy Research Working Paper 3777, The World Bank, 2005.

Department of Environment. *Bangladesh National Implementation Plan for Management of Persistent Organic Pollutants*. Dhaka, Bangladesh, 2007. Available online at http://www.neeri.res.in/Stockholm/NIP_Bangladesh.pdf.

Dupas, P. "Short-Run Subsidies and Long-Run Adoption of New Health Products: Evidence from a Field Experiment." Working Paper 011, University of California Center for Effective Global Action, Berkeley, CA, 2012. Available online at http://escholarship.org/uc/item/24s1q8d6.

Foster, A. D., and M. R. Rosenzweig. "Learning by Doing and Learning from Others: Human Capital and Technical Change in Agriculture." *Journal of Political Economy* 103(1995):1176–1209.

Gunnell, D., and M. Eddleston. "Suicide by Intentional Ingestion of Pesticides: A Continuing Tragedy in Developing Countries." *International Journal of Epidemiology* 32(2003):902–909.

Hainsworth, S. D., and S. J. Eden-Green. "Sustaining Change: Proceedings of a Workshop on the Factors Affecting Uptake and Adoption of Department for International Development (DFID) Crop Protection Program (CPP) Research Outputs." Wye, Kent, UK: Natural Resources International Limited, 2000. Available online at http://r4d.dfid.gov.uk/PDF/Outputs/CropProtection/CPPSustainingChange.pdf.

Haque, J. T. "Agrarian Transition and Livelihoods of the Rural Poor: Agriculture Extension Services." Working Paper, Unnayan Onneshan, Dhaka, Bangladesh, 2012. Available online at http://www.unnayan.org/reports/agri/AgricultureExt.pdf.

Kremer, M., and E. Miguel. "The Illusion of Sustainability." *Quarterly Journal of Economics* 122(2007):1007–1065.

Lichtenberg, E., and R. Zimmerman. "Information and Farmers' Attitudes about Pesticides, Water Quality, and Related Environmental Effects." *Agriculture, Ecosystems & Environment* 73(1999):227–236.

Liu, E. M., and J. Huang. "Risk Preferences and Pesticide Use by Cotton Farmers in China." *Journal of Development Economics* 103(2013):202–215.

Lopes Soares, W., and M. Firpo de Souza Porto. "Estimating the Social Cost of Pesticide Use: An Assessment from Acute Poisoning in Brazil." *Ecological Economics* 68(2009):2721–2728.

Ministry of Agriculture. *The Pesticide Rules Gazette*. Dhaka, Bangladesh: Ministry of Agriculture, Government of Bangladesh, 1985.

Ministry of Foreign Affairs of Denmark. "DANIDA: ASPS Phase II." 2012. Available online at http://bangladesh.um.dk/en/danida-en/agriculture-sector-programme-support/asps-phase-ii/.

Munshi, K. "Social Learning in a Heterogeneous Population: Technology Diffusion in the Indian Green Revolution." *Journal of Development Economics* 73(2004):185–213.

Palis, F. G., R. J. Flor, H. Warburton, and M. Hossain. "Our Farmers at Risk: Behaviour and Belief System in Pesticide Safety." *Journal of Public Health* 28(2006):43–48.

Pimentel, D. "Environmental and Economic Costs of the Application of Pesticides Primarily in the United States." *Environment, Development and Sustainability* 7(2005):229–252.

Pingali, P. L., C. B. Marquez, and F. G. Palis. "Pesticides and Philippine Rice Farmer Health: A Medical and Economic Analysis." *American Journal of Agricultural Economics* 76(1994):587–592.

Rahman, S. "Farm-Level Pesticide Use in Bangladesh: Determinants and Awareness." *Agriculture, Ecosystems & Environment* 95(2003):241–252.

Rejesus, R. M., F. G. Palis, A. V. Lapitan, T. T. N. Chi, and M. Hossain. "The Impact of Integrated Pest Management Information Dissemination Methods on Insecticide Use and Efficiency: Evidence from Rice Producers in South Vietnam." *Applied Economic Perspectives and Policy* 31(2009):814–833.

Richter, E. D. "Acute Human Pesticide Poisoning." In D. Pimentel, ed., *Encyclopedia of Pest Management,* New York: Dekker, 2002, 3–5.

Ricker-Gilbert, J., G. W. Norton, J. Alwang, M. Miah, and G. Feder. "Cost-Effectiveness of Alternative Integrated Pest Management Extension Methods: An Example from Bangladesh." *Applied Economic Perspectives and Policy* 30(2008):252–269.

Robinson, E. J. Z., S. R. Das, and T. B. C. Chancellor. "Motivations behind Farmers' Pesticide Use in Bangladesh Rice Farming." *Agriculture and Human Values* 24(2007):323–332.

van den Berg, H., and J. Jiggins. "Investing in Farmers—The Impacts of Farmer Field Schools in Relation to Integrated Pest Management." *World Development* 35(2007):663–686.

Vapnek, J., I. Pagotto, and M. Kwoka. *Designing National Pesticide Legislation*. Rome: Food and Agriculture Organization of the United Nations, 2007.

Wolff, H. "Economics of Tomato Production with Special Reference to Aspects of Plant Protection: A Case Study of Two Tomato Production Systems in Brong-Ahafo Region, Ghana." In *Ghanaian-German Project for Integrated Crop Protection,* Eschborn, Germany: GTZ, 1999.

Wolff, H., and G. Recke. "Path Dependence and Implementation Strategies for Integrated Pest Management." *Quarterly Journal of International Agriculture* 39(2000):149–171.

World Health Organization. *WHO Recommended Classification of Pesticides by Hazard and Guidelines to Classification 2009*. Geneva: Joint publication by the World Health Organization (WHO) International Programme on Chemical Safety (IPCS) and the Inter-Organization Programme for the Sound Management of Chemicals (IOMC), 2010.

World Resources Institute, United Nations Environment Programme, United Nations Development Programme, and World Bank. *World Resources, 1998-99: A Guide to the Global Environment: Environmental Change and Human Health*. New York: Oxford University Press, 1998.

Zilberman, D., A. Schmitz, G. Casterline, E. Lichtenberg, and J. B. Siebert. "The Economics of Pesticide Use and Regulation." *Science* 253(1991):518–522.