Inducing Smallholders' Compliance with International Standards: Evidence from the Shrimp Aquaculture Sector in Vietnam

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Abstract:

While compliance with international standards is a major challenge for producers in developing countries, there is limited research on what motivates producers to comply. In this study, we consider the shrimp aquaculture sector, in which the use of prohibited antibiotics by farmers has been a problem. We consider a case in Southern Vietnam and examine how to induce changes in the behavior of small-scale farmers to comply with international standards by conducting a randomized controlled trial with three interventions: a) providing a technical workshop, b) quantifying the unobserved residue level of antibiotics, and c) offering price premiums for higher quality shrimp. Using three years of panel data, we estimate the intention-to-treat effects of each intervention and find that quantifying the residue level had strong positive effects in improving knowledge and practices and reducing the probability of detecting antibiotics ex post. In particular, these effects were mainly driven by those farmers whose shrimp were detected to have positive amounts of antibiotics at the baseline. Our results suggest that providing easy access to laboratories to quantify the quality of shrimp is an effective way to solve the antibiotic residue problems in aquacultural sector.

Keywords:

RCT, standards, quality information, price incentive, aquaculture, Vietnam

JEL Codes:

O13, O22, O33, Q22

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1. Introduction

Compliance with international standards is one of the key challenges that prevents producers in developing countries from accessing global markets, particularly for high value-added products (Henson and Jaffee 2006, Humphrey 2008, Handschuch *et al*. 2013). It is a challenge because it requires production and management skills that are technically difficult for producers in developing countries to acquire and because different markets require different types and levels of standards (Henson and Humphrey 2010). Achieving high quality consistently is also difficult, particularly when the production is decentralized, involving numerous smallholders. Some horticultural sectors, such as bananas, are dominated by large-scale production; however, the comparative advantages of smallholders in labor-intensive crops (Hayami 2002), difficulty in acquiring large-scale land, marketing risks (Suzuki *et al*. 2011), and the optimal management scale contribute to the continued importance of smallholders as producers.

Studies on international standards thus far have focused on whether raising food standards works as a barrier for producers in developing countries or as a catalyst for further development (Henson and Jaffee 2006, Anders and Caswell 2009, Maertens and Swinnen 2009, Lee *et al*. 2012, Xiang *et al*. 2012, Hansen and Trifkovic, 2014). Literature on trade and development typically analyze the impacts on those who are certified and uncertified (Asfaw *et al*. 2010, Minten *et al*. 2018). Some studies have focused on how the increasing dominance of supermarket chains is imposing private standards directly onto producers and enhancing the concentration of producers (Reardon *et al*. 2003). Broader impacts of standards and certification on producer welfare, political economy, and market competitions are also modeled in other studies (Auriol and Schilizzi 2015, Swinnen 2016 and 2017). However, there is limited research that examines the problem from producers' point of views and scrutinizes the binding constraints for producers to comply with these food standards.

Qualities required in these high-value agricultural markets are generally high and often not readily observable, such as residue levels or sugar content levels. These qualities are defined as "credence attributes" in consumer market research; they are not directly observed by consumers, neither before nor after the purchase and include environmental, social, and health impacts of the production process (Nelson 1970, Auriol and Schilizzi 2015).[1] The recent rise in consumer awareness is increasing the importance of these unobserved credence attributes of high-value crops and adding

[1] Other categories are search attributes, which can be observed by consumers before purchase, such as price and color, and experience attributes, which consumers know only after they purchase and experience them, such as taste.

difficulty for producers to comply with standards.

Another complicating factor in developing country markets is that crops of different quality levels (i.e., complying and non-complying crops) often co-exist and are priced equivalently. This is due to the inabilities of the producers to signal their quality to traders and of the traders to reveal the true quality of crops by means of conducting costly tests because traders themselves are also often small-scale and resource-constrained. It is a typical "Lemon's problem (Akerlof 1970)," where quality uncertainty results in inefficiency. This co-existence of uneven quality products has been observed in many markets. Rau and Tongeren (2007) developed a theoretical model of a market in which complying and non-complying producers co-exist and examined how the imposition of external standards influences the markets of importing and exporting countries. They applied their model to the Polish meat sector, which faced compliance issues with EU standards. The Japanese rice market also experienced a similar situation at the beginning of the Meiji era in the 1860s when the privatization of the rice market resulted in diversified qualities of rice in the same market, which decreased the prices. It was only when local governments launched a strict monitoring and evaluation system to distinguish different rice quality levels that they were priced differently (Arimoto 2017).

These markets may mature over time, and appropriate prices for different qualities maybe assigned, thereby separating the markets. However, for an exporting country of high-value crops, it is important to move to that stage quickly because, in this age of global competition, they can easily lose market shares. If exported crops do not meet the standards of international markets and get shipped back, it is harmful not only for the company that exported the rejected shipment but also for other exporters in the same country due to the negative spillover on the country's reputation. Developed country markets regularly make public the list of previous rejection cases with names of exporters, country of origin, and the reasons for rejection, in such databases as RASFF for the EU, OASIS for the US, and the Ministry of Health for Japan (United Nations Industrial Development Organization (UNIDO) and Institute of Developing Economics (IDE) 2013). Jouanjean (2012) and Jouanjean *et al*. (2015) provide quantitative evidence on how port rejection affected the decline in trade volume ex post. Tran *et al*. (2012), using the case of crustacean exports, also shows quantitatively that imposition of stricter standards led to a decline in bilateral trade volume when exporting countries were not able to comply. Thus, it is important to understand the bottlenecks that prevent smallholders from complying with international standards.

In this study, we examine how we can induce changes in the behavior of small-scale farmers to comply with international standards, particularly on the use of antibiotics. We consider a case of the shrimp aquaculture in Southern Vietnam based on a randomized controlled trial (RCT) with three interventions. Shrimp farming has been known for its potential environmental damage, and thus international principles and guidelines for good farming practices have been developed. Many governments also set food quality standards. In many Asian countries, shrimp is predominantly raised by small-scale farmers on their plots, which are made into ponds.[2] One of the major challenges with shrimp farming is frequent disease outbreak, and in order to prevent and/or treat diseases, the use of antibiotics, which is prohibited internationally, was still common among smallholders at the time of the survey (Suzuki and Nam 2018). The use of antibiotics is a common concern in aquaculture, particularly at the early stage of development of the sector (United States Government Accountability Office 2017, Anderson *et al*. 2019). An earlier study found that the rejection rate of fishery products is high in Vietnam, and the top reason was the detection of prohibited substances in the bodies of fishery products, indicating that the main problem occurs at the farm-level rather than in later downstream stages of the supply chain (UNIDO and IDE 2013). This raises the question of why smallholders still use prohibited chemicals in farming, even though many international guidelines are in place.

Based on our preliminary fieldwork, we hypothesize three explanations for why smallholders continue using prohibited antibiotics: i) farmers lack technical knowledge, ii) farmers are not aware of the true quality of shrimp as the residues are unobserved unless tested, and iii) farmers do not have financial incentives to adopt good practices even if they are aware of them. For each hypothesis, we design an RCT to examine the causal impacts. The three interventions are as follows: a technical workshop, delivering farmers the residue test results of their own shrimp, and offering price premiums if their shrimp passed the quality test post-program.

Using panel data from 2015, 2016, and 2017, we estimate the intention-to-treat effects (ITT) of each intervention based on fixed-effect estimations. We examined the effects of our interventions on the knowledge, practice, residue detection, yield, and financial outcomes of shrimp farming. We find that among the three interventions, quantifying the quality (residue tests) had positive effects on increasing knowledge, improving practices, and reducing the probability of detecting residues ex post. In magnitude, quantifying quality of shrimp leads to a reduction in the probability of detecting residues above the maximum residue level by 28.2%. However, it did not lead to higher yields, higher prices, nor better financial outcomes. We also find that these

[2] One major exception is Indonesia (Derek 2004).

positive effects were much stronger for the sub-sample of farmers whose shrimp were detected positive amounts of residues ex ante. We also conduct several analyses on the attrition of our sample and confirmed that our results are robust. We further estimated the Treatment effect on the Treated (TOT), using the random invitation status to the workshop as the IV to correct for possible endogeneity of participation and confirmed that the results are consistent with our ITT.

Our study offers three main contributions. First, it is one of the first studies that have shown the effects of quantifying the unobserved quality of agricultural products on farmers' behaviors. The effects of quantifying the unobserved quality on people's behaviors are often examined in health or environmental literature, especially in the context of water contamination (Bennear and Olmstead 2008, Lucas *et al*. 2011). In particular, whether providing information on arsenic contamination in water changes people's behavior is a well-examined topic, and positive effects have often been found (Madajewicz *et al*. 2007, Bennear *et al*. 2013). Jalan and Somanathan (2008) examined the use of tap water and showed that informing consumers about the true quality of their drinking water changes their measures to treat their water. However, to the best of our knowledge, the effects of quantifying crop quality on agricultural practices have not been explored. While Bold *et al*. (2017) tested the true contents of fertilizers and modern seeds in local markets in Uganda, their study is limited to the farmers' behavior as consumers of these inputs. Our study shows the direct effect of knowing the crop quality on farmers' production activity and essentially indicates that if you know your own grade, then you have better incentives to improve.

Second, it expands the standard compliance literature by focusing on the incentives and constraints of farmers to comply. As mentioned, most of the existing studies examine the effects of compliance or non-compliance with international standards (Henson and Jaffee 2006, Maertens and Swinnen 2009, Minten *et al*. 2018). While many show that standard compliance is beneficial for farmers, only a limited number of studies examine why some farmers are not complying despite the seeming profitability. Our study is an effort to address this question, at least partially, and show that unobserved quality may be one of the binding constraints.

Third, our findings provide practical policy implications for improving aquaculture sector in developing countries, which has been studied insufficiently by economists. While the aquaculture provides half of the world's fishery products and contributes to a greater share of animal protein consumed by humans than that of beef, there has been a lack of economics research in this area (Kobayashi *et al*. 2015, Anderson *et al*. 2019). A majority of aquaculture production takes place in developing countries in Asia and is carried out by small-scale farmers. Our study suggests that providing easy access to public laboratories to test shrimp residue or water quality could be effective in providing producers with important information for their farming activity. In fact, the Thai government offers this service to producers, and this, coupled with other measures of shrimp farmer registration and a traceability system from shrimp seed to export, played a role in changing the smallholders' behaviors (Suzuki and Nam 2019).

The next section illustrates the contexts of our study site and theory of change. Section 3 provides details of our experimental design and data collection. Section 4 explains the estimation methods while Section 5 discusses the estimation results. The discussion and policy implications are presented in Section 6.

2. Study Context and Theory of Change

Study Site

We use a case of the shrimp aquaculture industry in Vietnam as it is one of the most successful export sectors in the country and yet has a high port rejection rate due to non-compliance with standards (UNIDO and IDE 2013). Similar to other Asian countries, about 80 percent of shrimp is produced by smallholders in Vietnam, who operate on less than 1 ha (Tran *et al*. 2013, Nguyen *et al*. 2019). Thus, we targeted our study to these small-scale farmers who reside in Ca Mau province, which is the southern-most province and is surrounded by the sea in Vietnam. Among the seven provinces in Southern Vietnam producing almost 90% of the total shrimp output of the country, Ca Mau is the largest shrimp-growing province in the country (VASEP 2019). It produces about 23% of the total shrimp production volume of Vietnam; Its exports in 2016 were worth 1 billion USD, which was 33% of the total exported shrimp value of Vietnam (VASEP 2019). In the past, the major economic activity was rice farming. In the late 1990s, the government allowed farmers to cultivate shrimp in this area, and many farmers converted their land to shrimp ponds. By the time of our survey in 2015, most farmers in the region were involved in shrimp farming. Black tiger shrimp used to be the most important category of fishery products in Ca Mau (MARD 2019). In recent years, farmers in Ca Mau province have been increasingly growing *Litopenaeus vannamei*, known as whiteleg shrimp, under the super-intensive model, which has a high stocking density (VASEP 2019). In Ca Mau province, there are a large number of small shrimp farmers and large shrimp processing and exporting firms.

The study was conducted in a coastal district, which is located in the south-west of Ca Mau province. The district has favorable natural conditions for intensive shrimp production. Physical infrastructure such as an inter-city main road has been upgraded by the local government. This has shortened traveling time to the center of Ca Mau province to about 40 minutes by car. There are nine villages in the district, and shrimp farmers are spread across these villages. Approximately 85% of the total land area is used for shrimp cultivation in the district (Ca Mau portal 2019). The shrimp farms are located in distant areas along one or two main canals, where shrimp farmers obtain their water.

Shrimp Farming and Market Structure

While wild-caught shrimp was a dominant form of procurement in the past, using ponds has now become dominant to meet the increasing global demand for shrimp. Shrimp farming can be categorized into several different methods depending on the density of the shrimp raised in the ponds, that is, extensive (2-5 pieces of shrimp seed/m^2), improved extensive (4-8 pieces/m^2), semi-intensive (9-15 pieces/m^2), intensive (70-150 pieces/m^2), and recently emerging super-intensive (250+pieces/m^3) production systems (Nguyen *et al.* 2019). For industrial purposes, intensive farming is conducted as it yields a greater amount, and in our study we focus on farmers who practice intensive and super intensive farming methods. One production cycle from stocking to harvest is about three months for whiteleg shrimp, which is the most popular type of shrimp in recent years. While the main shrimp crop seasons are twice a year (January to April and September to December), farmers may stock shrimp almost any time of the year and up to three times in a year. Farmers purchase shrimp larvae (or shrimp seed) from local hatcheries, stock them in their plots, and raise shrimp until they become large enough to sell. After stocking, farmers need to feed shrimp several times a day and check the health of shrimp as well as the water quality of the ponds.

According to the official statistics of Ca Mau Province, the profit per hectare (ha) per round of stocking was 0.6 billion to 2.5 billion Vietnamese Dong (VND), which is 25,000 to 107,000 US Dollars (USD), depending on the commune[3] (Ca Mau portal, 2019). This shows the high profitability of shrimp farming in the area. According to the Network of Aquaculture Centres in Asia-Pacific (2011) estimate of farming variable cost, about 60% of the total cost is used for the feed purchase, while the shrimp larvae cost accounts for about 10% and another 10% for the fuel cost.

While profitability is high for shrimp farming, one major challenge is the possibility of disease outbreak. Farmers mentioned that shrimp are sensitive to their environment, and their conditions may change very rapidly in a day. Once a problem

[3] Communes are the third-tier administrative division of Vietnam, after provinces and districts.

occurs, all shrimp in a pond may die.[4] Thus, it is still common among farmers to use antibiotics for the prevention and treatment of diseases although some of them are prohibited internationally (Suzuki and Nam 2019, Lee *et al*. 2019). These may remain in the bodies of shrimp, and if residues above the standards are detected by the ports of importing countries, they are rejected.[5,6]

Typically, shrimp are purchased by so-called "collectors" who reside in villages. They purchase shrimp from various shrimp farmers in the area and transport them alive to processing factories in iced boxes. Collectors usually purchase shrimp based on the size of the shrimp and hardly check the residue levels. Because one farmer's pond is not large enough to fill one container, several farmers' shrimp are often combined and sold together. This makes traceability at this stage of the supply chain difficult. Many exporter-processors have their own laboratory facilities and test antibiotics residue before purchasing. However, shrimp traders are almost always able to find some outlets to sell their shrimp because exporter-processors usually sell to multiple markets that require different levels of residue standards. Indeed, they target different markets based on the shrimp quality, and there is always a local market if exporters do not purchase. For exporter-processors, it is safer to source shrimp from their own managed ponds, but the share of shrimp from their own ponds is only about 20%, even for the largest exporter in this sector. Unlike the catfish sector (Trifković 2016), vertical integration or contract farming has not become common in shrimp sector in Vietnam. The major reasons mentioned by the exporter-processors for this limited level of vertical integration are the unavailability of large-scale land and optimal management scale due to the sensitivity and production risks involved in shrimp farming. Exporter-processors often have a list of registered traders and relatively large-scale farmers to purchase shrimp from, but most purchases are still on s spot-market basis.

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[4] Because of this sensitivity in shrimp farming, frequent exchanges of information among farmers is an effective way to promote good practices (Lee *et al.* 2019, Lee and Suzuki 2020).

[5] Note that a government body named the NAFIQAD tests for residues at Vietnamese ports. However, according to experts, residue tests at the ports of importing countries may yield different results mainly for two reasons. First, testing shrimp samples properly requires high skill and precision. Second, unlike testing liquid which is mostly uniform in what is contained, each piece of shrimp may contain different levels of residue and because these tests are based on random samples, it is never 100% possible to detect all the residues. This again reinforces the importance of having farmers comply with international standards.

[6] Among many kinds of international standards relevant for the shrimp sector in Vietnam, such as VietG.A.P., GlobalG.A.P., and ShAD by the Aquaculture Stewardship Council (ASC), our focus here is the maximum residue level of antibiotics as it is one of the major reasons for port rejections. Readers interested in other standards may refer to Marchke and Wilkings (2014), for example.

Theory of Change

With the market structure as above, indeed the small-scale farmers are acting rationally by not investing in shrimp quality. High assurance of market outlets, which do not test the antibiotic residue at the time of purchase, discourages farmers to avoid its use even if they may be aware that these are prohibited internationally. Their priority is on harvesting shrimp successfully, not on producing high quality of shrimp, and in order to minimize the probability of disastrous disease outbreak, farmers may use antibiotics for prevention. The issue of antibiotics use is aggravated as it may also occur unintentionally as some shrimp feeds include antibiotics and farmers are likely not aware of all components of their feed.

Collectors, who do not have means to test for the residue, may be hurt directly as the shrimp are tested by their buyers (exporter-processors), who may reject or offer lower prices for such shrimp. However, collectors can always adjust the purchase price of shrimp ex ante in expectation of the probabilistic occurrence of these cases. The shrimp market at farmers' stage resembles the Akerlof's lemons market (1970). As the quality is unobserved and mixed at this stage, buyers offer low prices, driving good sellers away from the market and causing market inefficiency. A difference from the Akerlof's case is that the sellers (shrimp farmers) themselves may not be aware of the true quality of shrimp as the residue may originate in the feed.

While the use of antibiotics may not (seem to) hurt farmers in the short run in the current market structure, it could hurt the farmers as well as all the stakeholders in the shrimp sector as a whole through the development of a bad international reputation. The cases and the reasons for import rejection are made public by the importing countries, and the high incidence of rejection sends bad signals to buyers in the consumer country. In this highly globalized world, buyers can quickly change markets to source the shrimp if standard incompliance continues to be a problem. Thus, it should be of the interest for the stakeholders in the shrimp sector to change farmers' farming practices.

When the existing market does not provide good incentives for farmers to comply with standards, what could be done to induce their behavioral change? Based on our fieldwork, we formulated three hypotheses on why shrimp farmers in Vietnam continue to use antibiotics even though international standards and guidelines on good shrimp farming practices are available. We then conducted randomized controlled trials to test each hypothesis as follows.

Hypothesis 1: Farmers do not have adequate knowledge about shrimp farming.

Hypothesis 2: Farmers are not aware of the true antibiotic residue levels in their shrimp.

Hypothesis 3: Farmers are not motivated to adopt good practices because sales prices do not meet the cost of adopting these practices.

For hypothesis 1, although agricultural extension officers and donor organizations have been providing workshops to disseminate knowledge on these practices, they may still lack the required knowledge on prohibited antibiotics and alternative methods to prevent disease outbreaks. Thus, we conducted a technical workshop to provide relevant information for farmers. The second hypothesis follows the previous argument that antibiotics may remain in the bodies of shrimp either by farmers' intentional use of them or by the feed that farmers use. The residues are unobserved unless tested and ordinary farmers do not have access to the laboratories; thus, they may not know the true quality of their shrimp. This lack of knowledge may discourage farmers to adopt good practices. Lastly, farmers may not adopt good practices because the costs of doing so do not meet the sales prices. As we mentioned, we find that the collectors do not add premiums for good shrimp. To test this hypothesis, we provided a price premium for high-quality shrimp. The details of these experiments are explained in the next section.

3. Experimental Design and Data

Surveys

We conducted three surveys in 2015, 2016, and 2017 targeting shrimp farmers who practice intensive shrimp production and designed an RCT with three interventions. The timeline of our survey and interventions is depicted in Figure 1. For our baseline survey in 2015, we selected 204 shrimp farmers randomly from the total list of 1,546 shrimp farmers in the district provided by the government of Ca Mau province and followed them up with surveys in 2016 and 2017. Panel surveys often face the threat of attrition, and so did our case. Below, we explain how we analyzed the attrition in our survey and what this means for our results. Also note that our data include financial performance and, as some of the answers given by farmers were unrealistically high, we consider that these answers are unreliable. Thus, we followed the principle of dropping observations that had more than three standard deviations above or below the means of the revenue and cost variables.[7] The final numbers of observations in each year are summarized in Table 1. Our questionnaire included questions on the socio-economic characteristics of farmers, land use, shrimp and agricultural production, marketing practices, knowledge, financial performances, and risk and time preferences. We collected information on current farming practices as of the survey years, while the production and sales information were from the year preceding the survey year. In the

[7] The total number of resulting outlier households was 8 in three years.

final post-program survey, information on crops in the year 2016 and in the months between January and August in 2017 were collected. As the 2017 production information is necessary to evaluate the effects of our final intervention (Figure 1), in analyzing models on production and sales, we used information during these months (January to August) only in each production year from 2014 to 2017 to make the data comparable across years. We trained our enumerators by ourselves and they were all fluent in local languages.

We also conducted residue tests of our sample farmers in 2015 and 2017, in collaboration with the College of Aquaculture and Fisheries, Can Tho University, which is the largest university in aquaculture in Southern Vietnam. The team of Can Tho University visited all of our sample farmers and collected shrimp samples directly. These were stored in an insulated box with ice and transported to the university's laboratory. The shrimp were tested for four types of antibiotics, namely *chloramphenicol* (CAP), *enrofloxacin* (ENR), *ciprofloxacin* (CIP), and *oxytetracycline* (OTC), which were the most frequently detected antibiotics and are regularly tested by exporter-processors in Vietnam (Tu *et al.* 2008, Flores-Miranda *et al.* 2012). For each chemical, the maximum residue level allowed is different, and this also differs across importing countries. We referred to the international food standards set by the Codex Alimentarius Commission (CODEX), which is jointly established by the United Nations Food and Agricultural Organization (FAO) and the World Health Organization (WHO), as well as the regulations by the Japanese government, as Japan is one of the largest countries of export for Vietnamese shrimp. According to these regulations, any detection of CAP is prohibited, while the maximum residue levels for OTC is 0.2 ppm. Further, Japan adopts a Positive List system, in which maximum residue levels are published for a specific group of chemicals while all other chemical residues are not allowed over 0.01 ppm. ENR and CIP fall into this category, and thus wet used these thresholds for our analyses. Collected shrimp were analyzed by the method of the Liquid Chromatography - Mass Spectrometry (LC-MS/MS) by the experts at Can Tho University.

RCT

To test our hypotheses, we designed an RCT with three interventions. The randomization was done at the individual farmer level. The first intervention was organizing a technical workshop to teach "Better Management Practices (BMP)," which were developed by the collaborative efforts of the Vietnamese government and international organizations, based on the *International Principles for Responsible Shrimp*

Farming issued by major international organizations, such as FAO and the World Wildlife Fund (WWF) (FAO/NACA/UNEP/WB/WWF 2006). We organized this workshop in October 2015 in the center of the targeted district and invited 150 farmers randomly out of our sample of 204 farmers. The sampling of treatment assignments and the number of observations for each survey are summarized in Table 1. We provided a transportation allowance to the participants, but unfortunately, only 78 farmers participated. Some of the reasons for not participating were that they had prior engagements or the training venue was too far. The lecturers were faculty members from Can Tho University, government officials from the Ministry of Agriculture and Rural Development in Ca Mau province, and an official from one private exporter-processing company. The lectures were mostly on technical issues, such as on the details of BMPs and how to prevent or treat diseases. We also had a discussion session in which farmers asked the lecturers questions. The lectures were 3.5 hours long in the morning, and we held the same workshop for two consecutive days so that farmers could attend at their own convenience.

The second intervention was for them to quantify the residues in their shrimp using laboratory tests. As explained earlier, we collected shrimp samples from farmers' ponds and tested them for residues in collaboration with Can Tho University. Among the 150 farmers invited to the workshop, we selected 50 farmers randomly to send the results of this residue test in the form of a letter. Other farmers were not informed of their results. The letter included information on whether the farmer's shrimp contained any of the four types of antibiotics, and if so, how much was detected. Each letter was written in the local language and delivered personally by our enumerator to the treated farmers in February 2016.

The final intervention was to offer a price premium for shrimp that passed the quality tests. We distributed price premium coupons to our treatment group farmers before they started raising their shrimp to examine whether this incentive would alter their behavior. These coupons were given to 40 shrimp farmers selected randomly from the 150 farmers invited to the workshop and could be redeemed if their shrimp passed the quality test offered by our research team, which was based on the antibiotics residue tests in 2017. The amount was 2 million VND (approximately 85 USD), which is about the price of 17 kg of shrimp output or equivalent to an agricultural labor wage for 10 days.[8] We distributed this coupon in December 2016 to targeted farmers and made the payments in January 2018 based on the residue tests.

[8] While this may be small, we were not allowed to distribute large amounts of premium in the local context.

Data

As Table 1 shows, we divided our sample into four groups: TG1 included farmers who were invited to the workshop only, TG2 included farmers who were invited to the workshop and the residue quantification intervention, TG3 included farmers who were invited to the workshop and the price premium intervention, and the rest were in the control group. As noted, while the actual participants in the workshop were about half of the farmers who were invited, all the farmers invited for residue quantification and price premium interventions actually received the treatments because our enumerators hand-delivered those letters and coupons to them. Thus, self-selection in the intervention was only applicable to workshop participants.

To examine whether our randomization was successful, we provided the average values of major baseline socio-economic variables and outcome variables that we used for our analyses by each group, as shown in Table 2. The results of the t-tests between a pair of groups are provided in Columns (5) to (10). For the socio-economic characteristics, overall farmers were not noticeably different across groups, except for the years of education, which were slightly lower for the TG1 relative to others, and shrimp farming experience between TG2 and the control group. Most of the farmers were male in our sample, indicating that shrimp farming is a male-dominated activity in this area. The average age was about 50 years old with an education of 7 to 8 years. Farmers had been farming shrimp for about 7 years on average. About 70% of farmers had training experience in shrimp farming, less than half of the farmers had ever tested their shrimp in a laboratory, and about 15% of farmers were also engaged in non-farm activities. Each farmer had about 2 to 3 plots, and the total size of their shrimp ponds was around 0.7 to 0.9 hectares. In terms of baseline socioeconomic characteristics, our randomization seems to have been successful.

Outcomes of our interests are farmers' knowledge, practice, chemical detection, yield, and financial outcomes. For each outcome, we used 1 or 2 indicators, whose definitions are summarized in Appendix Table 1. We focused on variables related to water quality management and input use as these are two most critical factors in shrimp farming. While most of outcome variables are not different across groups, two variables were statistically different. Less farmers in the TG3 (premium) test water daily relative to other groups, and less famers' shrimp in the TG1 were detected residues above the Maximum Residue Level than others.

The histograms of residue detection at the baseline and post-program are depicted in Figure 2. This shows that between the two years, the total detection of chemicals was reduced, likely because of efforts by the government or the private sector to raise awareness about the use of antibiotics. However, this trend was not homogeneous over the types of chemicals. While the probabilities of detecting CAP, ENR, and OTC decreased, that of CIP increased over time.

4. Estimation Methods

We examine the intention-to-treatment-effects (ITT) of our three interventions. While there is a selection issue for our workshop intervention due to a low take-up rate, we present the ITT results as this low take-up is often observed in experimental studies and reflects farmers' choices of participation in a real setting, which would be useful for policy consideration. We estimate the following:

$$\mathrm{y}_{it} = \sum_{j=1}^{3} \boldsymbol{P}'_{ij}\boldsymbol{\beta} + \sum_{t=1}^{2\ or\ 3} \boldsymbol{T}'_{it}\boldsymbol{\delta} + \sum_{j=1}^{3} \sum_{t=2\ or\ 3}^{3\ or\ 4} (\boldsymbol{P}_{ij} * \boldsymbol{T}_{it})'\boldsymbol{\varphi} + \alpha_i + u_{it}$$

where y_{it} is a set of outcome variables for an individual *i* at time *t*, $\boldsymbol{P}_{ij}$ is a vector that equals 1 if the individual *i* is in treatment group *j* and 0 otherwise, $\boldsymbol{T}_{it}$ is a year dummy variable, α_i is individual fixed effects, and u_{it} is the error term. We are interested in examining whether φ is statistically significant on this equation. Note that $\boldsymbol{T}_{it}$ is from 1 to 4 (2014 to 2017) in our models for production and sales while it is from 1 to 3 (2015 to 2017) in other models as explained in the survey section. For y_{it}, we have 15 variables under 5 categories of knowledge, practice, detection, yield, and financial performance (Appendix Table 1). For $\boldsymbol{P}_{ij}$, we have three treatment groups: workshop (Workshop), quantification of residues (Quality Info), and price premium (Premium). In yield and financial performance models, we additionally controlled for the total pond size as this is likely to affect the production outcomes. We also conducted sub-sample analyses by dividing farmers into two groups, the former being those farmers whose shrimp were detected positive amounts of residues at the baseline survey and the latter being those farmers whose shrimp were detected negative. Similar analyses that decompose a treatment group depending on the types of testing results were conducted in Jalan and Somanathan (2008) to show the differing impacts of the information.

For robustness check, we also estimated the treatment-effect-on-the treated (TOT), relying on fixed effect IV estimations with the random invitation status to the workshop as an IV for the workshop participation. Selection bias was not a concern for other two interventions as all those who were selected randomly received the treatment. The TOT results are not presented for brevity, but we confirm they were consistent with the ITT results given. We use cluster-robust standard errors at the household level.

One important assumption that the difference-in-differences (DID) method relies on is the parallel assumption (or common trend assumption), which states that the treatment and control groups would move in the same manner if there was no treatment at all. As shown in Table 2, we observed that farmers' socioeconomic characteristics were not noticeably different across groups at the baseline with the exception of years of education. Based on this and the fact that the treatment was chosen randomly, there is no particular reason to believe that these groups would act differently if there was no intervention. While we acknowledge that some outcome variables were different for some groups at the baseline, we note that the use of the panel data removes all of the time-invariant unobserved effects.

Another potential concern in our estimation was the small percentage of observations that detected a positive amount of residue. However, while this type of rare event regression is known to cause some bias when maximum likelihood estimations (MLE) are used, and several methods to reduce bias have been developed (e.g., King and Zeng 2001), our estimations do not rely on MLE. Further, as these correction methods are only applicable for cross-sectional data, we believe that using DID is a better option.

5. Estimation Results

Impacts of our Interventions

First, we examined whether our treatments had impacts on farmers' knowledge and practices (Table 3). Among the three interventions, quantifying quality of shrimp led to an increase in the farmers' knowledge of prohibited chemical immediately after the intervention and a higher probability of keeping farming records two years after the intervention. In magnitude, receiving shrimp quality information increased the probability of knowing prohibited chemical by 17% and the probability of keeping records by 22%. It is notable that the quality information intervention had a sustained effect over time. On the other hand, being invited to the workshop reduced the probability of keeping records by 20% in 2017. This reduction may be partly explained by the low participation rate among those who were invited to the training and partly due to the fading effects of workshop, which was held in 2015. Price premium intervention did not have significant impacts on neither knowledge nor practices. Note that most of the year dummy variables are positive and statistically significant, indicating that over the three years, farmers' knowledge and practice improved over time in general, including farmers in the control group. This may have had some effects in dampening the impacts of our interventions.

Effects on chemical detection are summarized in Table 4. We again find that coefficients of quality information intervention are all negative and statistically significant for ENR (enrofloxacin) and overall detection (columns (2) and (5)), indicating that receiving the antibiotics residue information on farmers' own shrimp can reduce the probability of detecting antibiotics residues ex post. In magnitude, it can reduce the probability of detecting at least one antibiotic above MRL by 28.2%. No other interventions had statistically significant effects on detection results.

We then examined whether these interventions had positive effects on increasing yields and financial outcomes in Table 5. We find that none of the interventions had statistically significant effects on yields, which is understandable given that our interventions did not directly aim to increase the yields. None of the interventions led to higher price either, although the probability of detection became lower for the quantifying quality group in 2017. This illuminates the unresponsiveness of the local shrimp prices to their quality, confirming the situation we learned during fieldwork. None of our interventions had statistically significant impacts on the revenue nor production costs either.

We further conducted sub sample analyses, separating the samples into those farmers whose shrimp were detected positive amounts of residues at the baseline survey (panel A) and those whose shrimp were not (panel B) in Tables 6 and 7. We find that the positive effects we found for the quality information intervention on knowledge, practice, and chemical detection were attributed to those farmers who had positive antibiotics residue detection at the baseline (Table 6, panel A, columns (1), (4), and (6)). In panel B, we notice that the same quality information intervention had an opposite effect of increasing the probability of detecting antibiotics residues for those farmers who were tested negative at the baseline. While we need to be cautious on treating these results due to the small size of sub-samples, these suggest that when we control for the possible inherent baseline difference between farmers in having residue detection, the quantifying quality intervention led farmers to improve upon farming practices for those farmers who received the bad news (positive detection) while the good news (no detection) led farmers to relax and not pay too much attention to their farming practices ex post.

It is also interesting to observe that for those farmers tested positive at the baseline, the price premium intervention influenced improving their practice of water quality testing while the same effect was nonexistent for those farmers tested negative at the baseline (Table 6, column (3)). The price premium intervention also reduced the probability of detecting antibiotics residues above MRL for those farmers who had positive detection at the baseline while the same intervention had the opposite effect for those farmers who were tested negative at the baseline (Table 6, column (6)). These results suggest that there is indeed an inherent difference between farmers who had positive detection and who had no detection in how they respond to these interventions. Interestingly, those who were tested positive seem to be responding positively to the incentives offered by the interventions.

On yield and financial outcomes, we again observe differing responses between those farmers who were tested positive and those tested negative at the baseline (Table 7). Overall, the quality information and price premium interventions seem to have positive impacts for those farmers whose shrimp were tested positive for antibiotics at the baseline (panel A, columns (3) and (4)) while they had the opposite negative impacts for those who were tested negative at the baseline (panel B, columns (1) to (4)). The effects of workshop, however, are in the different direction from other two interventions. Those who had positive residues seemed to have reduced revenue while those who had not detected residues had better outcomes (panel B, columns (1) to (4)). While it is difficult to confirm exactly why the yield and financial outcome results differed between these groups as well as across interventions, the results from knowledge, practice, and detection in Table 6 are mostly in line with the results in Table 7. Positive impacts of the quality information and premium interventions for panel A in Table 6 seem to be the base for the positive impacts for the same group in Table 7, while the opposite also holds for panel B in both Tables. The insignificant effects found on yield and financial outcomes for all samples in Table 5 seemed to have driven from these differing responses between these two groups of farmers, providing nil effects on average.

To sum, we find that the quality information intervention had consistent positive effects of improving farmers' knowledge, practice, residue detection outcome while these effects did not translate into better yield or financial outcome when we examined the whole sample. When we divide farmers based on their status of antibiotics detection at the baseline, we find that the quality information and price premium interventions had positive impacts on knowledge, practice, residue detection, and financial outcomes for farmers who had positive detection at the baseline. However, for farmers who had negative detection at the baseline, these interventions worsened their outcomes post program. The workshop intervention did not improve farmers' outcomes in the whole sample. In the subsample analyses, those farmers with positive detection at the baseline reduced revenue while those tested negative at baseline had moderate improvement on yield and financial outcomes ex post.

Attrition Analyses

Long-term panel data is subject to attrition, and attrition may affect our randomization and threaten the internal validity of our analyses (Alderman *et al*. 2001). As Table 1 showed, our sample was reduced by 27% over time. Major reason for attrition was because farmers stopped cultivating shrimp over time. Shrimp farming is difficult and when farmers face disease outbreak, they may decide to go back to rice farming, which is less profitable but more stable. We conducted several methods to test whether this attrition was systematic. First, we tested whether the baseline characteristics were systematically different between those farmers who stayed in our survey until 2017 and those who dropped out (Table 8). We find that these variables were not so different between the two groups, except for age and sales price. Those who stayed tend to be older and received higher prices. Second, we examined whether attrition rate was different across treatment status. Table 9 shows the results of t-test on the attrition rate between each pair for 2016 and in 2017. We find that the difference was statistically significant between the Treatment Groups 1 (Workshop only) and 2 (Workshop + Quality Information) in 2017 while other pairs were not statistically different although the rate varied. Third, we examined whether the attrition status can be explained by our treatment status and baseline characteristics in Table 10. In all models, we find that those assigned to the Quality Information intervention were more likely to be dropped out of the survey. To examine who dropped out the survey more in detail, we divided the Quality Information intervention into those farmers whose shrimp were detected positive amounts of residues at the baseline and those who had no detection in columns (2) and (4). We find that it was those farmers who did not have any detection at the baseline that left our survey. It may be that receiving good news (no detection) reduces incentives to continue cooperating with the surveys as the farmer becomes more confident with his farming practices. While we cannot confirm why, at least we can say that having more attritors from this Quality Information group does not mean that our finding that this group had positive results were not affected by having positively detected farmers leaving the survey.

Since we find that attrition was systematically greater for a particular group, we used attrition weights to re-estimate our main regressions (Fitzgerald *et al*. 1998). We first conduct a logit estimation using the baseline data with the dependent variable equals to 1 if the farmer stayed in the survey until 2017 and 0 otherwise and the control variables which are the same as the ones used in Table 10. The inverse of the predicted value for staying in the survey was used as weights in our fixed effect estimations. As Table 11 shows, the main results still hold. Those farmers who received the residue test results of their own shrimp improved their knowledge and practice in shrimp farming ex post. The probability of residue detection from this group also declined after the intervention.

6. Discussion and Policy Implications

In this study, we examined how we can induce smallholders to comply with international standards when the markets for complied and non-complied crops are not clearly separated, using a case of shrimp farming in Southern Vietnam. We designed a randomized controlled trial with three interventions to test whether giving farmers technical knowledge, quantifying the unobserved residue level of antibiotics in their shrimp, or offering price premiums for shrimp with higher quality would change their farming behaviors.

We found that quantifying quality information led farmers to have better knowledge, improve on their farming practice, and face a lower probability of detecting prohibited residues ex post. In magnitude, receiving the results of residue tests decreased the likelihood of detecting at least one chemical by 28%. These positive effects did not translate into higher yields nor better financial outcomes based on the whole sample. When we divide the sample into those whose shrimp were detected positive amounts of residues and those who did not at the baseline, we find that the positive impacts of our interventions came mostly from the former group of farmers. For these group of farmers, the quantifying quality information and price premium interventions improved their knowledge, farming practice, the probability of detection, and some financial outcomes while for the other group of farmers, contrasting results were found. Our results were robust to the attrition analyses. We also discuss possible reasons why quantifying quality may induce farmers' behavioral changes. One limitations of our study is the small number of observations and multiple number of treatments. While our intention to have multiple treatments was to compare the effects of different interventions on outcomes together, we acknowledge that this design reduces the power of estimation.

Based on our findings, farmers in our study site were not following good practices because they were not aware of the true quality of their shrimp, supporting our Hypothesis 2. Providing them with a means to quantify the quality of their crop can trigger behavioral changes among farmers to comply with international standards. Why, then, do farmers have incentives to change their behavior with this knowledge, particularly when it is not accompanied with apparent financial incentives? It could simply be their willingness to improve upon their farming when they become aware of their own "grades" which are objectively measured. Another possibility is that it is rather their awareness that someone other than themselves (i.e., our project) also know their shrimp quality that motivated them to change their behavior. This is likely in our study context as the rumors tend to spread rapidly among rural villages, and the farmers are aware that our project is also supported by their local government. Both mechanisms could be functioning together, and a separate experiment is called for to answer that question. The ineffectiveness of the workshop intervention probably suggests that farmers are already aware of the technical information provided during the workshops. The insignificance of price premium intervention was unexpected, and it is possible that if the amount of reward was higher, the results may have been different.

Another interesting finding was contrasting results between those farmers who had positive amounts of detection at the baseline and those who did not, particularly for the quality information and price premium treatment groups. As seen in Tables 6 and 7, those farmers who had positive detection at the baseline tended to have better outcomes ex post. While the difference between "good news (no detection)" and "bad news (positive detection)" can explain the results for quality information intervention, farmers in the price premium intervention were not given their shrimp quality information. Then what caused these contrasting results? We note that there are two types of farmers in panel A (positive detection at baseline), namely, those farmers who were intentionally using antibiotics to prevent or treat shrimp disease and those who were not aware that their feeds or inputs included antibiotics. If all the farmers were unintentionally using them, it is difficult to explain why we observe the contrasting results between panels A and B in Tables 6 and 7. Thus, it seems likely that at least a good share of farmers was using antibiotics intentionally and decided to change the behaviors responding to our interventions.

Our findings show that providing easy access to laboratory tests for smallholders is an effective way to solve a problem of non-compliance of international standards by smallholders regarding the antibiotics use. This is a feasible and available option for governments. In fact, this is in place in Thailand, where antibiotic residue is no longer an issue (Suzuki and Nam 2016 and 2019). The government provides free access to laboratories and assures the traceablity of shrimp from hatcheries to export by requiring documents at each stage of the supply chain. The government in Taiwan also plays an important role in having a good aquaculture governance by requiring registration for farmers and offering subsidies and other support services only to those registered farmers (Chen and Qiu 2014). In the long run, separate markets for complied and non-complied crops need to be developed so that farmers can capture the gains from compliance. Our study shows that providing easy access to laboratory testing may work as a step toward building these markets.

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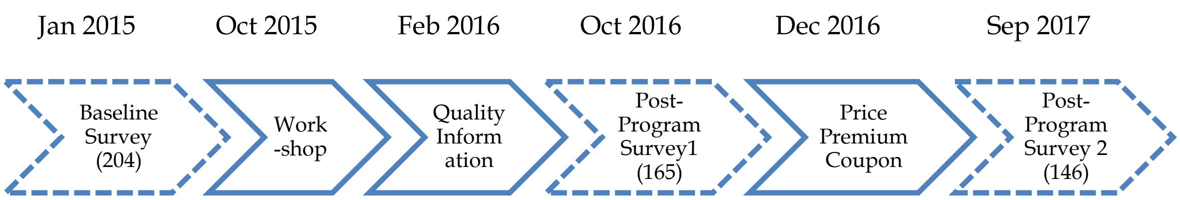
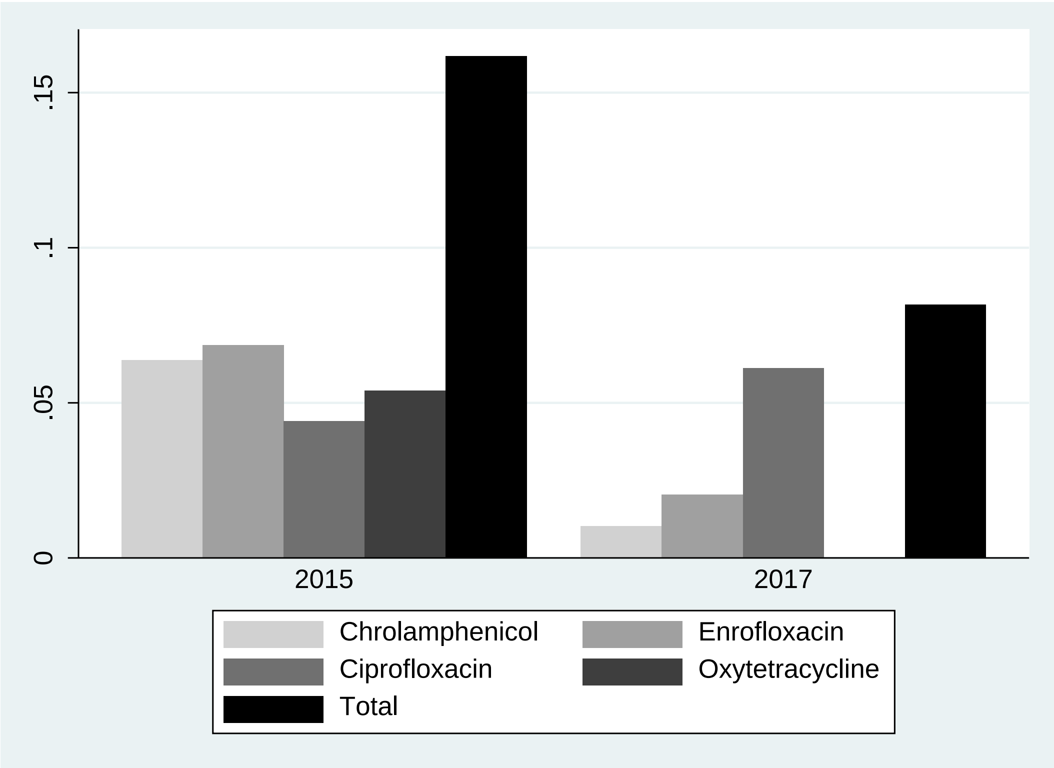
Tables and Figures

Figure 1: Timeline



Note) Numbers in parentheses indicate the number of observations interviewed at each round.

Figure 2: Distribution of Residue Detection by Survey Year



Source) Authors' Survey

Table 1: Number of Observations by Group and Survey Year

	Observed			Attritors	
	2015	2016	2017	2016	2017
	(1)	(2)	(3)	(4)	(5)
TG1:	60	50	48	8 (0.13)	10 (0.17)
TG2:	50	39	30	11 (0.22)	20 (0.40)
TG3:	40	33	29	4 (0.10)	11 (0.28)
Control Group	54	43	39	10 (0.19)	15 (0.28)
Total:	204	165	146	33 (0.16)	56 (0.27)

Note) TG1: Workshop Invitation only, TG2: Workshop Invitation + Quality Information, TG3: Workshop Invitation + Price Premium. Shares of attrited observations to the original sample indicated in parentheses.

Table 2: Summary Statistics of Baseline Characteristics by Each Group

	TG1 (60)	TG2 (50)	TG3 (40)	Control (54)	Differences between:					
					1& 2	1& 3	1& C	2& 3	2& C	3& C
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Female	0.07	0.08	0.03	0.07						
	(0.26)	(0.28)	(0.16)	(0.26)						
Age	50.68	51.1	50.68	50.96						
	(11.05)	(11.30)	(11.39)	(12.27)						
Education years	7.19	8.55	8.38	8.41	**	*	**			
	(3.09)	(3.01)	(2.74)	(3.08)						
Years of shrimp cultivation	8.04	6.10	7.2	8.24					*	
	(8.85)	(5.37)	(5.65)	(6.80)						
# HH members	4.23	4.08	4.43	4.00						
	(1.67)	(2.01)	(1.75)	(1.75)						
=1 if have training experience	0.75	0.72	0.68	0.67						
	(0.44)	(0.45)	(0.47)	(0.48)						
=1 if have tested shrimp	0.47	0.38	0.48	0.39						
	(0.50)	(0.49)	(0.51)	(0.49)						
=1 if engaged in non-farm activity	0.15	0.18	0.15	0.09						
	(0.36)	(0.39)	(0.36)	(0.29)						
# plots	3.03	2.54	2.53	2.72						
	(2.85)	(1.61)	(1.96)	(1.86)						
Total pond size (ha)	0.91	0.82	0.71	0.97						
	(1.02)	(0.81)	(0.53)	(1.04)						
Knowledge on prohibited chemical	0.12	0.18	0.23	0.19						
	(0.32)	(0.39)	(0.42)	(0.39)						
Knowledge on water quality	2.16	2.10	1.95	2.04						
	(0.87)	(0.71)	(0.78)	(0.82)						
=1 if test water quality daily	0.35	0.5	0.25	0.43				**		*
	(0.48)	(0.51)	(0.44)	(0.50)						
=1 if keep records	0.33	0.33	0.39	0.39						
	(0.40)	(0.40)	(0.39)	(0.39)						
ln (Shrimp density (#seed/ha/time) +1)	13.43	13.11	12.92	13.06						
	(0.88)	(2.16)	(2.39)	(2.17)						
=1 if at least one residue detected above MRL	0.1	0.22	0.23	0.13	*	*				
	(0.30)	(0.42)	(0.42)	(0.34)						
Quantity harvest (kg)	1499	1543	1467	2197						
	(2383)	(3427)	(1600)	(2688)						
Quantity harvested/ Quantity of seed inputs (kg/pcs)	0.009	0.007	0.010	0.010						
	(0.01)	(0.01)	(0.01)	(0.01)						
Price/kg (USD)	5.28	4.52	5.37	4.68						
	(1.92)	(1.75)	(1.94)	(1.46)						
ln (Revenue)	5.74	4.39	5.80	5.93						
	(5.11)	(4.97)	(4.99)	(5.06)						
ln (Seed & feed cost)	7.60	6.54	6.61	6.38						
	(4.03)	(4.28)	(4.14)	(4.40)						

Note) TG1: Workshop Invitation only, TG2: Workshop Invitation + Quality Information, TG3: Workshop Invitation + Price Premium. Standard deviations reported in parentheses. Data for production outcomes (quantity harvested, ratio of harvest to seed, price, ln(revenue), and ln(cost)) correspond to production and sales between January and August in 2014 as these months are used for the regressions conducted in the paper. Columns (5) to (10) report statistical significance between each pair of groups. * p<0.1; ** p<0.05.

Table 3: ITT Effects on Knowledge and Practice of Shrimp Farming

	Knowledge		Practice		
	Prohibited chemical	Water quality (10 max)	Test water daily	Keep records	ln Shrimp density
	(1)	(2)	(3)	(4)	(5)
Workshop x 2016	0.006	0.062	-0.001	-0.029	-0.457
	(0.05)	(0.16)	(0.01)	(0.28)	(1.13)
Workshop x 2017	-0.019	-0.676	-0.01	-0.200*	-0.594
	(0.16)	(1.19)	(0.07)	(1.67)	(0.82)
Quality info x 2016	0.170*	-0.074	-0.182	0.079	0.182
	(1.70)	(0.15)	(1.30)	(0.74)	(0.43)
Quality info x 2017	0.000	0.161	0.041	0.216*	0.27
	(0.00)	(0.24)	(0.28)	(1.78))	(0.40)
Premium x 2017	-0.089	0.815	0.22	-0.045	0.873
	(0.71)	(1.21)	(1.60)	(0.37)	(1.58)
2016	0.260***	1.187***	0.183*	0.144*	0.314
	(2.61)	(3.81)	(1.93)	(1.70)	(0.91)
2017	0.637***	3.950***	0.219**	0.247***	-0.237
	(6.91)	(9.62)	(2.13)	(2.72)	(0.45)
Constant	0.171***	2.088***	0.381***	0.345***	13.159***
	(7.74)	(23.48)	(14.02)	(15.34)	(115.92)
N	515	512	515	510	504
R2	0.368	0.468	0.091	0.065	0.032
Wald χ^2	30.59***	42.71***	4.68***	2.92***	1.43

Note) Results of FE reported. Numbers in parentheses indicate absolute values of t-statistics based on clustered standard errors at individual household level. * p<0.1; ** p<0.05; *** p<0.01.

Table 4: ITT Effects on Detection of Prohibited Chemical Residues on Shrimp Samples

	Chemical Detection				
	=1 if detected above MRL				=1 if one detected above MRL
	CAP	ENR	CIP	OTC	
	(1)	(2)	(3)	(4)	(5)
Workshop x 2017	-0.030	-0.000	0.030	0.008	-0.03
	(1.01)	(0.00)	(0.48)	(0.17)	(0.36)
Quality info x 2017	-0.032	-0.188*	-0.093	-0.095	-0.282**
	(0.47)	(1.90)	(0.83)	(1.07)	(2.34)
Premium x 2017	-0.100	-0.000	0.057	-0.057	-0.057
	(1.30)	(0.00)	(0.62)	(0.85)	(0.45)
2017	-0.000	0.000	0.000	-0.038	0.000
	(.)	(0.00)	(0.00)	(1.01)	(0.00)
Constant	0.063***	0.063***	0.043***	0.056***	0.162***
	(8.86)	(7.42)	(4.13)	(7.18)	(12.05)
N	302	302	302	302	302
R2	0.097	0.08	0.027	0.082	0.098
Wald χ^2			0.59	1.61	2.16*

Note) CAP: *chrolamphenicol* (>0ppm), ENR: *enrofloxacin* (>0.01ppm), CIP: *ciprofloxacin* (>0.01ppm), OTC: *oxytetracycline* (>0.2ppm). Results of FE reported. Numbers in parentheses indicate absolute values of t-statistics based on clustered standard errors at individual household level. * p<0.1; ** p<0.05; *** p<0.01.

Table 5: ITT Effects on Outcome of Shrimp Farming

	Yield		Financial Outcome		
	Ave quantity harvested (kg)	Ave harvest/ seed inputs (kg/pieces)	Average price/kg (USD)	ln total revenue	ln total input cost
	(1)	(2)	(3)	(4)	(5)
Workshop x 2016	-15894	-0.067	-0.127	-1.705	-0.178
	(1.01)	(0.84)	(0.17)	(1.47)	(0.25)
Workshop x 2017	-6189	-0.009	2.126	1.501	-0.299
	(0.91)	(0.24)	(1.35)	(0.82)	(0.34)
Quality Info x 2016	-119.5	-0.002	0.215	1.035	-0.877
	(0.29)	(0.38)	(0.31)	(0.86)	(1.04)
Quality Info x 2017	-339.1	-0.005	-0.957	1.409	-0.36
	(0.80)	(0.96)	(0.93)	(0.75)	(0.42)
Premium x 2017	-164.3	-0.001	0.053	-0.005	-0.766
	(0.46)	(0.32)	(0.06)	(0.00)	(1.15)
Total plot size (ha)	1083.3	0.008	0.805	-0.269	0.503
	(0.82)	(1.08)	(1.33)	(0.57)	(1.10)
2015	-295.3	0.003	-1.372***	0.203	1.217***
	(0.57)	(0.83)	(3.44)	(0.36)	(2.99)
2016	15608	0.067	-1.982***	0.743	0.945
	((0.97)	(0.82)	(3.44)	(0.75)	(1.49)
2017	6417	0.016	-3.430***	-0.939	2.014***
	(0.91)	(0.41)	(2.64)	(0.72)	(2.87)
Constant	38.51	0.002	4.475***	5.610***	6.375***
	(0.02)	(0.11)	(8.91)	(10.11)	(13.45)
N	462	462	357	514	514
R2	0.034	0.023	0.181	0.02	0.056
Wald χ^2	1.23	1.6	5.75***	0.91	2.18**

Note) Results of FE reported. Numbers in parentheses indicate absolute values of t-statistics based on clustered standard errors at individual household level. * *p*<0.1; ** *p*<0.05; *** *p*<0.01.

Table 6: Sub-sample Analysis: ITT Effects on Knowledge, Practice, and Detection

	Knowledge		Practice			Detection
	Prohibited chemical	Water quality (10 max)	Test water daily	Keep records	ln Shrimp density	=1 if one detected above MRL
	(1)	(2)	(3)	(4)	(5)	(6)
A: Positive Detection at Baseline						
Workshop x 2016	0.07	-0.833	-0.278	-0.141	-0.446	
	(0.29)	(0.94)	(1.52)	(0.69)	(0.59)	
Workshop x 2017	-0.238	-1.371	-0.412	-0.237	-0.485	0.119
	(1.04)	(1.34)	(1.65)	(0.89)	(0.27)	(0.50)
Quality info x 2016	0.321*	0.805	-0.274	0.205	-0.745	
	(1.69)	(0.91)	(1.01)	(0.91)	(1.02)	
Quality info x 2017	0.097	0.793	0.195	0.406*	-0.452	-0.548**
	(0.41)	(0.67)	(0.99)	(1.85)	(0.26)	(2.31)
Premium x 2017	0.217	1.475	0.662***	0.183	2.224	-0.458*
	(0.93)	(1.44)	(2.84)	(0.78)	(1.59)	(1.93)
N	144	144	144	142	142	83
R2	0.405	0.518	0.199	0.097	0.105	0.572
Wald χ^2	11.95***	16.54***	3.39***	1.61	2.07*	8.13***
B: Negative Detection at Baseline						
Workshop x 2016	-0.025	0.437	0.117	0.018	-0.442	
	(0.19)	(1.05)	(0.81)	(0.15)	(0.90)	
Workshop x 2017	0.054	-0.416	0.124	-0.194	-0.713	-0.105
	(0.39)	(0.61)	(0.82)	(1.46)	(0.98)	(1.48)
Quality info x 2016	0.111	-0.425	-0.145	0.031	0.542	
	(0.94)	(0.74)	(0.88)	(0.25)	(1.05)	
Quality info x 2017	-0.016	-0.069	0.019	0.144	0.729	0.000***
	(0.12)	(0.09)	(0.10)	(0.95)	(1.21)	(4.99)
Premium x 2017	-0.222	0.521	0.054	-0.156	0.337	0.200*
	(1.52)	(0.60)	(0.34)	(1.09)	(0.64)	(1.91)
N	371	368	371	368	362	219
R2	0.371	0.454	0.089	0.069	0.022	0.162
Wald χ^2	24.03***	29.93***	3.27***	2.26**	1.08	

Note) Results of FE reported. Numbers in parentheses indicate absolute values of t-statistics based on clustered standard errors at individual household level. * $p<0.1$; ** $p<0.05$; *** $p<0.01$.

Table 7: Sub-sample Analysis: ITT Effects on Outcome of Shrimp Farming

	Yield		Financial Outcome		
	Ave quantity harvested (kg)	Ave harvest/ seed inputs (kg/pieces)	Average price/kg (USD)	ln total revenue	ln total input cost
	(1)	(2)	(3)	(4)	(5)
A: Positive Detection at Baseline					
Workshop x 2016	-65700	-0.329	-1.336	-4.656***	-1.206
	(1.04)	(1.04)	(1.10)	(2.76)	(1.02)
Workshop x 2017	-14356	-0.064	-1.981	-4.072	-1.939
	(0.95)	(0.83)	(0.93)	(1.13)	(1.55)
Quality Info x 2016	-2599	-0.012	0.549	5.135**	0.056
	(0.54)	(0.52)	(0.48)	(2.53)	(0.06)
Quality Info x 2017	-2502	-0.014	0.924	10.899***	0.782
	(0.56)	(0.55)	(0.53)	(3.62)	(0.55)
Premium x 2017	-158.4	0.003	3.282**	5.886**	-0.408
	(0.09)	(0.28)	(2.38)	(2.13)	(0.59)
N	134	134	105	147	147
R2	0.143	0.142	0.27	0.185	0.064
Wald χ^2	1.01	1.62	2.64**	5.41***	1.21
B: Negative Detection at Baseline					
Workshop x 2016	70.841	0.017	0.414	-0.655	0.166
	(0.18)	(1.13)	(0.46)	(0.46)	(0.19)
Workshop x 2017	1034.5**	0.032*	3.462*	3.411*	0.237
	(2.47)	(1.69)	(1.95)	(1.79)	(0.21)
Quality Info x 2016	-232.0	-0.004	0.227	-0.32	-1.13
	(0.54)	(0.55)	(0.25)	(0.22)	(0.99)
Quality Info x 2017	-754.98*	-0.008	-1.376	-3.091*	-0.739
	(1.76)	(1.65)	(1.17)	(1.73)	(0.75)
Premium x 2017	-758.67**	-0.008**	-2.003**	-3.767**	-0.758
	(2.36)	(2.01)	(2.62)	(2.58)	(0.77)
N	328	328	252	367	367
R2	0.07	0.057	0.209	0.028	0.062
Wald χ^2	1.63	1.06	6.54***	1.55	1.6

Note) Results of FE reported. Numbers in parentheses indicate absolute values of t-statistics based on clustered standard errors at individual household level. Total pond size (ha) and production year dummies (2015~2017) are included though not reported for brevity. * p<0.1; ** p<0.05; *** p<0.01.

Table 8: Mean Comparison of Baseline Characteristics by Attrition Status

	Attrited (56) (1)	Stayed (148) (2)	Diff (3)
Female	0.07	0.06	
	(0.26)	(0.24)	
Age	46.8	52.4	**
	(10.35)	(11.48)	
Education years	8.58	7.91	
	(2.85)	(3.10)	
Years of shrimp cultivation	6.79	7.72	
	(6.69)	(7.10)	
# HH members	4.20	4.16	
	(1.94)	(1.73)	
=1 if have training experience	0.75	0.69	
	(0.44)	(0.46)	
=1 if have tested shrimp	0.34	0.46	
	(0.48)	(0.50)	
=1 if engaged in non-farm activity	0.14	0.14	
	(0.35)	(0.35)	
# plots	2.5	2.82	
	(1.44)	(2.38)	
Total plot size (ha)	0.783	0.896	
	(0.58)	(0.99)	
Knowledge on prohibited chemical	0.16	0.18	
	(0.37)	(0.38)	
Knowledge on water quality	2.09	2.06	
	(0.72)	(0.84)	
=1 if test water quality daily	0.43	0.37	
	(0.50)	(0.48)	
=1 if keep records	0.44	0.33	
	(0.41)	(0.38)	
ln shrimp density (#seed/ha/time)	13.0	13.2	
	(2.13)	(1.84)	
=1 if residue detected	0.11	0.18	
	(0.31)	(0.39)	
Quantity harvest (kg)	1174	1866	
	(1429)	(2946)	
Quantity harvested/ Quantity of seed inputs (kg/pcs)	0.0071	0.0097	
	(0.008)	(0.012)	
Price/kg (USD)	4.47	5.14	*
	(2.00)	(1.67)	
ln (Revenue)	4.90	5.67	
	(4.90)	(5.09)	
ln (Seed & feed cost)	6.33	7.03	
	(4.32)	(4.17)	

Note) Standard deviation in parentheses. Data for production outcomes (quantity harvested, ratio of harvest to seed, price, ln(revenue), and ln(cost)) correspond to production and sales between January and August in 2014 as these months are used for the regressions conducted in the paper. * p<0.1; ** p<0.5

Table 9: Difference in Attrition Rate by Groups

	2015-2016		2015-2017	
	Diff	p-value	Diff	p-value
	(1)	(2)	(3)	(4)
TG1 & TG2	-0.087	0.24	-0.233	0.01***
	(0.07)		(0.08)	
TG1 & TG3	0.033	0.62	-0.108	0.20
	(0.07)		(0.08)	
TG1 & TG4	-0.052	0.45	-0.111	0.16
	(0.07)		(0.08)	
TG2 & TG3	0.12	0.13	0.125	0.22
	(0.08)		(0.10)	
TG2 & TG4	0.035	0.66	0.122	0.19
	(0.08)		(0.09)	
TG3 & TG4	-0.085	0.26	-0.003	0.98
	(0.07)		(0.09)	

Note) TG1: Workshop Invitation only, TG2: Workshop Invitation + Quality Information, TG3: Workshop Invitation + Price Premium. Standard errors reported in parentheses. *** $p<0.01$

Table 10: Probit Model Estimates for Attrition Analysis

	=1 if Attrited			
	(1)	(2)	(3)	(4)
Workshop	-0.130	-0.130	-0.130	-0.130
	(1.38)	(1.38)	(1.29)	(1.29)
Quality Information	0.254***		0.210**	
	(2.62)		(2.02)	
Quality Information (Detected negative)		0.303***		0.227*
		(2.81)		(1.94)
Quality Information (Detected positive)		0.144		0.182
		(0.93)		(1.13)
Price Premium	0.129	0.129	0.129	0.129
	(1.23)	(1.23)	(1.23)	(1.23)
Female			0.00	0.00
			(0.03)	(0.04)
Age			0.005	0.008
			(0.04)	(0.06)
Education years			-0.008***	-0.008***
			(2.64)	(2.60)
Years of shrimp cultivation			-0.001	-0.001
			(0.11)	(0.13)
# HH members			-0.003	-0.003
			(0.16)	(0.15)
=1 if have training experience			0.11	0.109
			(1.61)	(1.59)
=1 if have tested shrimp			-0.071	-0.069
			(1.02)	(0.99)
=1 if engaged in non-farm activity			0.064	0.061
			(0.60)	(0.57)
# plots			-0.014	-0.014
			(1.06)	(1.06)
N	204	204	190	190
Pseudo R2	0.032	0.036	0.136	0.181
Wald χ^2	7.33*	8.42*	17.36*	17.41*

Note) Marginal effects reported. Numbers in parentheses indicate absolute values of t-statistics based on clustered standard errors at individual level. ***<0.01, ** *p*<0.05, * p<0.1. Controls include:

Table 11: ITT Effects with Attrition Weights

	Knowledge			Practice		Residue	Yield		Financial Outcome		
	Chemical	Water	Test water	Record	ln(density)	Detection	Harvest	Harv/Seed	Price/kg	ln(rev)	ln(cost)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
WS x 16	-0.018	0.012	-0.039	-0.039	-0.444		-13833.9	-0.057	-0.03	-1.605	-0.419
	(0.15)	(0.03)	(0.31)	(0.35)	(1.21)		(0.99)	(0.81)	(0.04)	(1.28)	(0.60)
WS x 17	-0.054	-0.764	0.001	-0.178	-0.718	-0.031	-5727.05	-0.008	2.457	1.49	0.118
	(0.43)	(1.20)	(0.01)	(1.42)	(0.97)	(0.34)	(0.88)	(0.22)	(1.54)	(0.75)	(0.12)
QI x 16	0.206*	-0.175	-0.172	0.135	-0.128		-186.117	-0.003	0.116	1.12	-1.08
	(1.94)	(0.35)	(1.15)	(1.25)	(0.50)		(0.45)	(0.49)	(0.15)	(0.88)	(1.15)
QI x 17	0.105	0.041	-0.086	0.236*	0.202	-0.281**	-471.652	-0.007	-1.551	1.114	-0.687
	(0.92)	(0.06)	(0.57)	(1.86)	(0.28)	(2.28)	(1.04)	(1.21)	(1.50)	(0.58)	(0.73)
PR x 17	-0.073	0.82	0.132	-0.062	0.937	-0.054	-287.118	-0.003	-0.48	-0.464	-0.856
	(0.57)	(1.16)	(0.95)	(0.49)	(1.60)	(0.41)	(0.72)	(0.63)	(0.53)	(0.26)	(1.11)
N	480	477	480	475	471	280	433	433	333	480	480
R2	0.365	0.456	0.088	0.073	0.042	0.096	0.029	0.02	0.208	0.02	0.054
Wald χ^2	29.08***	35.38***	4.33***	3.21***	1.54	2.03*	1.42	1.61	6.38***	0.83	1.85*

Note) WS: Workshop, QI: Quality Info, PR: Price premium. Numbers in parentheses indicate absolute values of t-statistics based on clustered standard errors at individual level. ***<0.01, ** *p*<0.05, * p<0.1. Year dummies (2016, 2017) are included in models (1) to (6). Production year dummies (2015, 2016, 2017) and total plot size included in models (7) to (11).

Appendix Table 1: Definition of Dependent Variables

Category	Variables	Range	Definition
Knowledge	Prohibited chemical	1 or 0	=1 if answered yes to the question of "Do you know which chemical is prohibited to use internationally?" and were able to answer at least one such chemical =0 otherwise
	Water quality	10 max	Number of water qualities that farmers were able to name
Practice	Test water daily	1 or 0	=1 if answered "everyday" to the open question of "When do you test water quality?" =0 otherwise
	Keep records	0 to 1	Asked farmers whether they keep records of the six aspects during farming (water quality, seed use, input use, feeding, sales price, and sales volume). For each aspect, farmers were given 1 if answered yes. Then the scores were summed over and divided by 6 to get an average.
	ln shrimp density		Log of average shrimp seed pieces/ha/time of all plots that farmers have
Detection	CAP, ENR, CIP, OTC, =1 if one detected above the Maximum Residue Level (MRL)	1 or 0	=1 if detected by the laboratory test =0 otherwise
Yield	Ave quantity harvested	kg	Average quantity harvested across all plots
	Ave harvested/ seed inputs	kg/pieces	Average ratio of quantity harvested to quantity of seed across all plots
Financial Outcomes	Ave price/kg	USD	Average price/kg across all sales & plots
	ln (Revenue/ha/time)		Log of total revenue from all salles & plots
	ln (Input cost/ha/time)		Log of total input cost from all plots

Note) For Yield and Financial Outcomes, the data correspond to production and sales between January and August in the respective year. For logged variables, 1 is added before taking the logarithm.