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To cluster or not to cluster farmers? Influences on network interactions, risk perceptions, and adoption of aquaculture practices

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ABSTRACT

Over the course of just a few years, shrimp farming has become a major aquaculture production system in coastal areas of several developing countries across the globe. However, farmers are facing a variety of risks related to disease, market, and climate, which influence risk management strategies and adoption of new technologies. This paper looks at three practices related to pond management: (1) water quality management to ensure a good environment for shrimp growth; (2) adequate feed input; and (3) disease control practices in order to mitigate the risk of disease outbreak in the pond. We investigated adoption of these three practices in smallholder shrimp farms in the Mekong Delta, by exploring how and whether membership into a producer's cluster influences access to knowledge and perception of risk in the adoption process. The results show that, after controlling for farm characteristics, farm clustering has a positive relationship with the adoption of water quality management, feed inputs, and disease control practices. Results also indicate that increasing interaction frequency with public sector and private sector's actors, as well as the perceived degree of market risk, positively influences the adoption of the three pond management practices under study. Mediation analyses show that being a member of a farmer cluster influences adoption of farming practices via two underlying processes: frequency of interaction with public and private sector's actors, and perception of market risk, both of which ultimately promote the adoption of practices. We conclude that clustering is a promising avenue for fostering interactions between farmers and key supporting actors in aquaculture, and impacts both the formation of specific aqua-related risk perceptions and subsequent practice adoption. As such, clusters – by fostering linkages and facilitating interactions between different knowledge sources – can promote adoption of practices toward sustainable intensification. However, to more effectively deploy a cluster approach a key policy and practice implication is to take into consideration local idiosyncrasies defined by their social interactions, risk perception and spatial dimensions in order to better facilitate local linkages between farms (horizontal coordination) and a better integration with the value chain (vertical coordination).

1. Introduction

Aquaculture is the fastest-growing food production sector of the last decade (FAO, 2015) and has the potential to contribute significantly to future food security on the planet (World Bank, 2013). The very dynamic sector boasts constant technological innovations. Shrimp farming is a prominent example of the aquaculture success story, with rapid expansion supported by technological advances and international policies (Béné, 2005). Over the course of just a few years, shrimp farming has become a major aquaculture production system in the coastal areas of several developing countries across the globe. This growth has not come about without social and environmental consequences (Ottinger et al., 2016), but after two decades of growth, shrimp farming is considered a driver of economic development in coastal areas (Ahmed, 2013). It created the emergence of a small-scale entrepreneurial farming sector in many of the top aquaculture-producing countries in the world (Belton et al., 2017), such as Vietnam, India, and Thailand. While vertically integrated industrial farms exist and contribute significantly to the global supply, small-scale producers continue to play an important role in the sector.

Whereas the sector is characterized by continuous growth, there is much volatility involved herein. Small-scale farmers are continuously

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challenged to improve their production systems. In addition to have to meet quality and food safety requirements to enter the global value chain (Omoto and Scott, 2016; Hatanaka, 2010; Vandergeest, 2007), they also face technical challenges. Risks in farming are both high and varied (Flaherty et al., 2009; Ahsan, 2011; Muniesa et al., 2017) and include production risks (e.g. farm management, input and water quality), disease risks (e.g. recurrent apparition of new diseases such as the recent outbreak of Acute Hepatopancreatic Necrosis Disease (AHPND) hitting the South East Asian shrimp industry) (Flegel, 2012; FAO, 2013) affecting the global value chain (Ababouch, 2015; World Bank, 2014), market risks (e.g. market price fluctuation, changes in market requirements), and climate risks (e.g. sudden temperature changes, drought or unpredictable rainfall (Kam et al., 2012). Risks play a paramount role and influence risk management strategies and adoption of new technologies (Aguilar-Gallegos et al., 2015; Case et al., 2017; Joffre et al., 2018; Lestariadi and Yamao, 2018; Marra et al., 2003). Following the industry's growth, the private sector, especially feed and inputs producers, proposed several technical changes mainly related to intensification of production and as a strategy to reduce aforementioned risks. Pathogen-free post larvae, high quality feed, feed additives, probiotic used to control pond and shrimp gut biota and use of a water treatment pond are just some of the numerous technologies that were developed. The technologies were also promoted by public extension services, private sector advisors and other knowledge sources (such as media, input retailers), and were partially adopted by farmers in order to mitigate risks and upgrade production systems (Ahsan, 2011; Hishamunda et al., 2009; Kabir et al., 2017). The practices related to pond management can be broadly grouped into three main categories: i) water quality management to ensure a good environment for shrimp growth, ii) adequate feed input, and iii) disease control practices in order to mitigate risk of disease outbreak in the pond.

In aquaculture, adoption of technologies and practices is often related to farm characteristics and stocking density (Johnson et al., 2014; Engle et al., 2017; Joffre and Bosma, 2009), while other variables that might influence adoption, are seldom investigated. However, research shows that risk-related issues influence adoption of new technologies or practices in farming (Marra et al., 2003). Adoption of new technologies and practices has a twofold relationship with risk: 1) whether expected returns in investment are realized (Marra et al., 2003) or whether there are unanticipated side-effects (Wigboldus et al., 2016) and 2) acknowledgement of risks in farming and practices that are adopted as a response to new technologies to mitigate these risks. This paper focuses on the latter, risk in relation to adoption. Risk perception and knowledge and information acquisition that influence the perception of farming risks are significant drivers during the technology and practice adoption processes. Some other (Abadi Ghadim et al., 2005; Greiner et al., 2009) factors are farm characteristics (Meuwissen et al., 2001), social capital (Hunecke et al., 2017) or the membership in a farming cluster (Flaten et al., 2005; Hendrikse and Bijman, 2002), to mention just a few (see Pannell et al., 2006 and Mills et al., 2017, for overview of factors).

This paper focuses primarily on cluster formation, which is often considered and promoted by government and development projects in order to mitigate production and market risks, integrate small-holders in the value chain (Hao et al., 2018; Jelsma et al., 2017; Dirven, 2001), and enhance adoption of new technologies and practices (Kilelu et al., 2017a). Agricultural clusters can be defined as "*the entire range of input-output linkages in production of and transactions in goods and services*" (Dirven, 2001). This definition encompasses the heterogeneity of clusters in terms of production system, value chain organization and the type of interactions between actors. The literature on agricultural clusters, describes them as having different forms of firm cooperation and interactions (Burger et al., 2001). Clusters are often assumed to enable collective action between producers who aim to reduce costs by improving their bargaining position (*horizontal coordination*) and linking producers to market and suppliers, which corresponds to *vertical coordination* (Kilelu et al., 2017a; Poulton et al., 2010; Burger et al., 2001; Heinen and Weijland, 1989). Combined horizontal and vertical coordination create a synergetic effect and are crucial for small-scale producers to remain competitive, overcome the limitations of bad access to services (including inputs and information), share costs of technology and practice adoption, and thereby mitigate different risk sources (Schmitz and Nadvi, 1999; Porter, 1998; Poulton et al., 2010; Molema et al., 2016).

Throughout aquaculture literature, clusters have been described primarily as horizontally coordinated to enable the establishment of formal farmers groups and, in turn, technology upgrading (Kassam et al., 2011; Martinez et al., 2004) (i.e. *farmer clusters)*. They have been described, less frequently, as so-called *agribusiness* clusters that are additionally focused on vertical coordination such as those in agriculture (Molema et al., 2016; Dirven, 2001; Kilelu et al., 2017b). A cluster management approach of small scale farmers in aquaculture has been found to foster financial and technical capacity of small-scale producers (Mohan and De Silva, 2010; Kassam et al., 2011; Ha et al., 2013), facilitate knowledge transfer (Srinath et al., 2000), and support horizontal coordination to mitigate disease risk at the landscape level (World Bank, 2014). Thus, aquaculture-oriented literature has identified some benefits of collective action for smallholder farmers such as when they join clusters in order to mitigate farming risks. However, there is a knowledge gap about how exactly the clusters contribute to upgrading technology and practices, and which underlying mechanisms within the clusters influence adoption of technologies and practices. This paper aims to contribute to closing this knowledge gap.

We use the case of shrimp farming in the Mekong Delta (Vietnam), where both the government and development organizations support clusters of producers. We aim to understand the relationship between farmer organizations and clusters in relation to the perception of farming risks and adoption of farming technologies and practices to mitigate the perceived production risks. Specifically, we investigate technology and practice adoption in smallholder shrimp farms in the Mekong Delta by exploring how membership into a farmer cluster influences access to knowledge and perception of risk in relation to adoption of risk-mitigating technologies and practices. We focus our analysis at the individual level (i.e. the farm). We break down our study in three research question: i) to what extent does membership into a farmer cluster influence adoption of technologies?; ii) how does participating in a farmer cluster influence interactions with actors within the farmer's network and perceptions of farming risks?; and iii) to what extent can interactions with actors within the farmer's network and the perception of farming risks explain the relationship between cluster membership and the adoption of technologies and practices to mitigate risk?

We test the hypothesis that farming intensity and farm size are not the only drivers of adoption of aquaculture practices and that adoption of different types of technology is determined by whether or not a farmer belongs to a farmer cluster. We also hypothesize that membership into farmer clusters influences underlying factors such as risk perception and access to knowledge sources, and that these underlying factors ultimately support the adoption of different types of farming technologies.

The paper is organized as follows. We first present the theoretical framework, then further develop our hypotheses on linkages between clusters, access to knowledge sources, risk perception, and adoption (Section 2). In Section 3 we present the study site and the methodology deployed to collect and analyze the data. Results on adoption of the technology and role of driving factors and underlying processes are presented in Section 4, followed by discussion (Section 5) and conclusion (Section 6).

2. Theoretical framework

Central to this paper is the notion that farming is not an individual

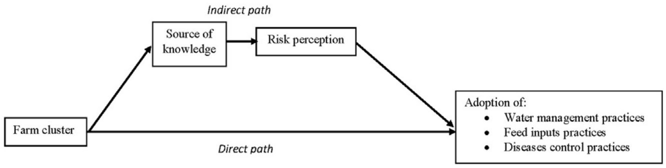

Fig. 1. Proposed research model.

enterprise; rather, it is organized within a social network of diverse actors tied to individual farmers (Oreszczyn et al., 2010). These ties can be inferred from geographical proximity, family or other private network ties, via contacts along the farming value chain, or other contacts such as with public sector partners. As such, a farmer's personal network can be regarded as a specific type of farm capital. Farmers can be influenced by various kinds of exchanges with their networks, for instance by knowledge exchanges, which can add to the farmers' capacity base (Thuo et al., 2014; Narayanam and Narahari, 2011). We expect these interactions to shape the formation of risk perceptions and subsequent adoption of particular farming practices to address the risks – see Fig. 1 for our research model. Our model does do not cover traditional determinants of adoption, such as farmer's characteristics (age, education level) or the economic dimension of adoption. Instead, it focuses on farmers' interactions with different actors and their influence on risk perception and adoption of practices. We feel that it is necessary to articulate these ideas because the adoption of farming practices includes risk management strategies and may logically arise from the particular risks a farmer perceives (cf. Joffre et al., 2018).

As mentioned in the introduction, the government and development organizations support farmer clusters as a means to exchange knowledge and promote technological upgrading. As extension services and private companies rely on farmer clusters to interact with farmers and share farming-related information, it comes as no surprise that clusters are common and efficient ways to reach multiple farmers in a single effort.

The exchanges that farmers have with others within their social networks are valuable because they can be utilized for learning and acquiring knowledge (cf. Darnon et al., 2007). Also, social interactions are a key source for shaping risk perceptions. Research suggests that a person's evaluation of risk is strongly influenced by interpersonal interactions (e.g., Joffe, 2003; Kasperson et al., 1988; Van der Linden, 2015). As shrimp farmers interact frequently with each other to discuss aspects of aquaculture, we expect these interactions to shape the formation of their perceptions related to relevant domains of risk that they face such as, disease risks, market risks, and climate risks. While we acknowledge the complexity of relationships and the collective and intra-cluster interaction processes that take place (Matous, 2015), we developed a model that measures the role cluster membership in relation to the diversity of source of knowledge and risk perception at the individual level of decision making (i.e., the farm) to test our hypotheses, in view of the significance of individual decision making in adoption of novelty in aquaculture farms (Kumar et al., 2018; Yi et al., 2018). We consider this as a first step of investigating the role and influence of farmer clusters in aquaculture technology adoption.

We specifically cover the three risk sources that are significant in shrimp farming. Disease risk corresponds to the risk of disease outbreak at the farm, which is a common hazard in shrimp farming (Piamsomboon et al., 2015; Hoa et al., 2011). Market risk relates to market price fluctuation, risk of input price increases or changes in market requirements that are well known to affect farmers' financial outcomes (Lestariadi and Yamao, 2018). Finally, climate risks encompass less predictable rainfall patterns, rising temperatures, and changes in saline water intrusion in production areas, which increasingly affect shrimp farming (Kam et al., 2012; Kabir et al., 2017).

As shrimp farming is a risky business, farmers' risk perceptions are important drivers for their risk management behaviors (Joffre et al., 2018). By forming specific risk perceptions an individual is able to protect oneself by targeting a specific (perceived) risk (Rogers, 1975). According to Rogers (1975), perceived risk is made up of a person's judgment of the severity and the susceptibility of the risk. The perception of risk *severity* determines how serious a farmer thinks a particular risk is, while risk *susceptibility* reflects how vulnerable to a given risk a farmer considers him/herself to be. As a whole, risk perceptions drive a farmer to adopt practices that will optimally protect the business, as people are motivated to choose behavioral options to neutralize or manage a particular risk (e.g., Poortvliet and Lokhorst, 2016).

3. Methods

3.1. Study site

The Mekong Delta in Vietnam is constantly transforming. Among the significant changes in land use, the rapid expansion of shrimp farming in the coastal areas started in the 1990s and continued until the early 2000s (Le et al., 2018). Within a decade, a new aquaculture sector emerged replacing traditional rice field and mangrove covers with shrimp ponds. In 2015, shrimp farming represented more than 650,000 ha for a production of 510,983 tons (GSO, 2015) dominated by small-scale farmers in terms of cultivated area and production (World Bank, 2014), and a limited number of large industrial and vertically integrated farms.

The farms are managed by individual households deploying a range of techniques and farming intensity, from extensive to intensive shrimp farming requiring high level of inputs (Boyd and Engle, 2017). Both of the main shrimp species raised, *Penaeus monodon* and *Penaeus vannamei*, are found in the landscape. The latter is now the most widely cultured while the two make up the dominant farmed shrimp species in the region.

With a dominance of smallholder farmers, the governmental and non-governmental strategy to upscale production, quality and the environmental performance of shrimp farms has focused on farmer clusters. Clusters in Vietnam are a form of farmer organization that promotes interactions between farmers while imposing fewer legal obligations on their members (Cooperative law 2003) and without the – potentially negative – collectivization connotation of previously government-supported cooperatives. In practice, farmer clusters are one of the outreach modalities that extension services and NGO projects use to facilitate improved managerial capacity for upgrading production, accessing market (Ha et al., 2013), and mitigating risks related to disease and degraded water quality (Dung et al., 2017). It addition, farmer clusters can facilitate linkages with feed and input dealers as well as processing companies in need to secure raw material. Not all shrimp farmers in Vietnam are part of a cluster. In 2008, 85 farm clusters were registered in Ca Mau province, the province with the largest shrimp culture area (Ha et al., 2013).

Compared to agribusiness clusters, shrimp farmer clusters in Vietnam do have some characteristics of agribusiness clusters related to linkages with actors within the value chain, and with a certain level of vertical coordination. However, there is a large heterogeneity in size (number of members) and in the quality of linkages between the clusters, inputs suppliers and processing companies (Ha et al., 2013). Furthermore, the primary focus of shrimp farmer clusters is horizontal coordination, at the producer level, to reduce risk of disease and improve management techniques to meet market requirements.

3.2. Survey

We conducted our survey in May 2017 in Soc Trang and Bac Lieu, two of the main producing provinces in Vietnam's Mekong Delta (Fig. 2). We interviewed 251 shrimp farmers. Survey sites were selected in collaboration with the local Department of Agriculture and Rural Development and included 11 survey sites across Soc Trang and Bac

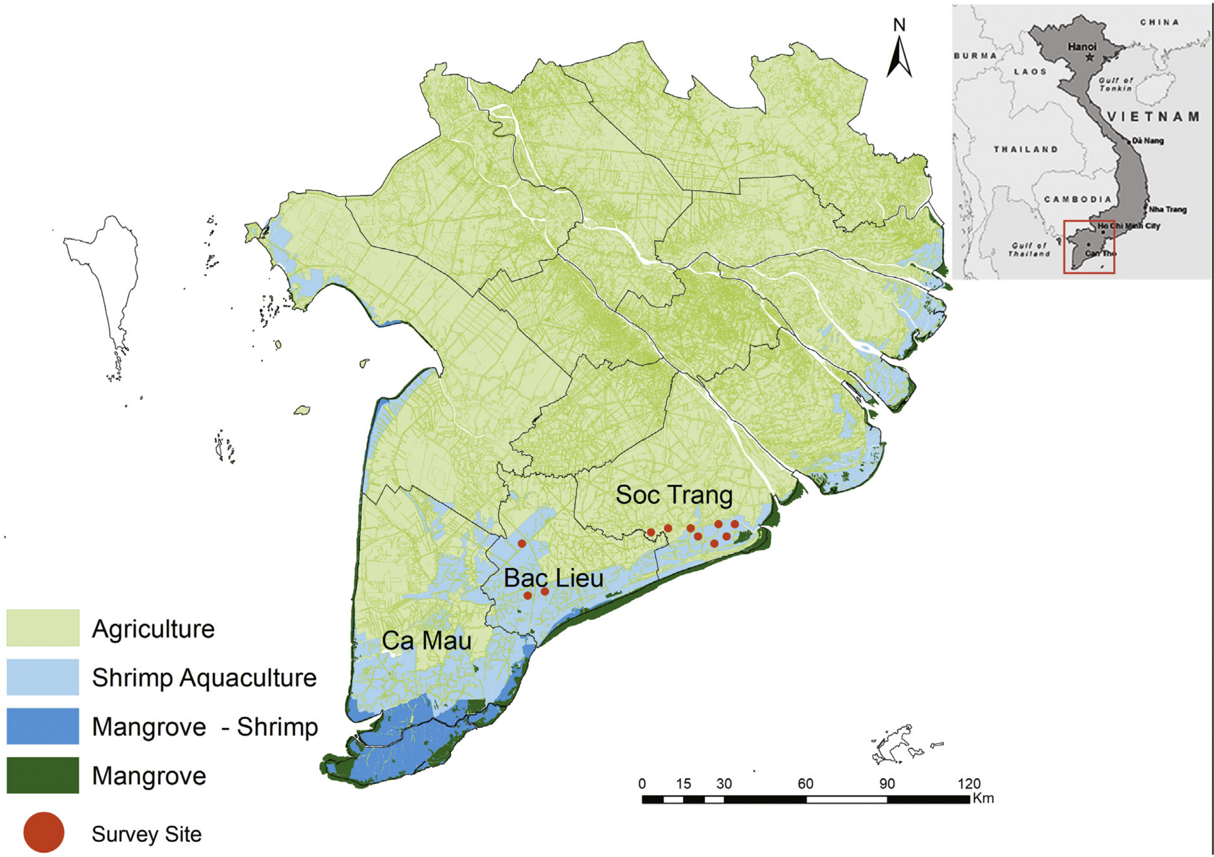

Fig. 2. Study area, Bac Lieu and Soc Trang provinces in the Mekong Delta and survey sites (indicated by red dots). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Lieu provinces. The sites were selected according to dominant farming intensity and to the presence or absence of farmer clusters. Within each area, surveyed hamlets were selected based on accessibility and farms were selected randomly. 34% of our sample was part of a 13 farmer clusters visited. Clusters varied from 5 to 65 members and 5 of the 13 clusters had specific arrangement with input suppliers (bulk purchase for economy of scale and bargaining) and processing companies to secure market prices. The diversity of farmer cluster organization, size and outside interactions make measurement of within-cluster interactions practically difficult, and hence render a multi-level analysis problematic to operationalize.

The survey was composed of several groups of questions, including farm characteristics (farmed area, number of ponds, stocking density of the two shrimp species), membership in a farm cluster, the frequency of interactions with different sources of knowledge, the perception of susceptibility and severity of different risk sources and the adoption of 14 aquaculture practices. Aquaculture practices included water quality management practices, disease control and feed inputs-related practices (see Appendix A). Selection of the 14 aquaculture practices was based on a consultation with local experts. The experts were asked to identify the most important practices used in shrimp farming in the Mekong Delta. The sources of knowledge explored were related to public sector actors that include extension services, model farmers, mass media (most media such as TV and radio in Vietnam are government-controlled and considered public sector), but also neighbors, and private sector actors (firm advisors, input retailers, shrimp buyers, and processing companies). Thirteen questions explored perceptions of risk susceptibility and severity in shrimp farming. The survey covered risk sources related to disease, climate and the risk's market type (see Appendix A). Questions related to adoption, frequency of interactions with knowledge sources and perception of risk were framed according to Likert-type scales (e.g. to assess likelihood of risk, 1 = very low; 5 = very high).

3.3. Analysis

For the analysis, we used farm characteristics as control variables. The different sources of knowledge were grouped into 3 categories: public sector, neighbors, and private sector interactions. The 14 aquaculture practices were grouped into 3 categories related to i) water quality management (use of probiotics to improve water quality; use of carbohydrate; water treatment pond; stocking of tilapia in treatment pond; use of quality test kit), ii) feed input (use of probiotics to improve digestion and shrimp gut health; high quality feed; use of vitamins and minerals); and iii) disease control practices (use of pathogen free PLs; high quality post larvae; deployment of biosecurity measure to prevent access of pathogens; use of antibiotics). The level of adoption of the new variables was computed by averaging the adoption level of the different practices making up this new variable.

The number of variables used to assess risk severity and susceptibility risk was reduced using a factor analysis. The Kaiser–Meyer–Olkin (KMO) measures of sampling adequacy for sources of risk showed a value of 0.70. The factors were rotated using VARIMAX with Kaiser Normalization, an orthogonal rotation procedure, to increase interpretability. Factor solutions with different numbers of factors were examined and a three-factor solution was selected using a scree plot method. Factor analyses yielded single-factor solutions with factor loadings above 0.40. Identified factors were then labeled on the basis of how individual items loaded on the factor. For the three dimension of risk, we constructed a factor representing climate risk, market risk and disease risk. In order to test our research model (Fig. 1), we first performed a series of hierarchical regression analyses, after which we performed a formal test of mediation to see whether source of knowledge and risk perception (middle blocks in Fig. 1) could explain the association between farm clustering and the adoption of farming practices.

The model aims at exploring what drives the adoption of three types of aquaculture practices: (1) water quality management, (2) feed inputs, and (3) disease control. To analyze these adoption processes, a series of three separate hierarchical regression analyses were performed, each focusing on one of the dependent variables. Each hierarchical regression analysis included four steps. In Step 1 control variables were entered: size of the farm in hectares, number of ponds, and densities of the two shrimp species; in step 2 our main independent variable – clustering – was included; by performing this step we wanted to establish whether clustering could predict the dependent variables beyond the farm characteristics (i.e. the control variables). Then, in Step 3 frequency of interactions with neighbors and public and private sector actors were added. Finally, in Step 4 perceptions of severity and susceptibility of disease risk, market risk, and climate risk were entered. These steps were aimed at establishing whether the association between clustering and farming practices would statistically reduce (i.e. their regression weights becoming smaller or insignificant) upon entering the hypothesized mediators: source of knowledge and risk perception.

Then, to finally formally test for mediation, a series of bootstrap analyses (Preacher and Hayes, 2004) was employed to test the reduction in the direct effect between clustering and the three different types of farming practices of interest. This approach involves computing 95% confidence intervals (CIs; 5000 bootstrap resamples) around indirect effects; mediation is indicated by CIs that do not contain zero.

4. Results

4.1. Descriptive statistics

Means and standard deviations of the study variables are reported in Table 1. Participants reported having frequent interactions with neighbors, and less frequent interaction with both public and private sector actors. Disease, market, and climate scored slightly higher for perceived severity than for perceived susceptibility. Disease risk scored higher than the other two types of risks – market and climate – for both perceived severity and perceived susceptibility. All average scores for the different practices studied (water quality management, input feed inputs, and disease control) were slightly below the measurement scale's the midpoint, with plausible variations in the responses. This indicates that our sample represents an adequate range of adoption.

4.2. Regression results

This study set out to investigate what drives three types of aquaculture practices, (1) water quality management, (2) feed inputs, and (3) disease control. Hence, a series of three separate hierarchical regression analyses were performed, each focusing on one of the dependent variables. As discussed, in Step 1 we entered farm characteristics as control variables: size of the farm in hectares, number of ponds, and densities of the two shrimp species; in step 2 the independent variable of clustering was included; in Step 3, frequency of interactions with neighbors and public and private sector actors were entered; finally, in Step 4 perceptions of severity and susceptibility of disease risk, market risk, and climate risk were entered.

Table 1
Means and standard deviations of the study variables.

	M	*SD*
Farm size	1.41	1.69
Number of ponds	2.54	1.71
Stocking density *P. vannamei*	24.24	28.66
Stocking density *P. monodon*	5.17	6.67
Public sector interactions	2.23	0.67
Neighbors interactions	4.47	0.77
Private sector interactions	1.39	0.54
Severity disease	3.76	0.87
Severity market	2.95	0.89
Severity climate	2.79	0.93
Susceptibility disease	3.10	0.86
Susceptibility market	2.81	0.87
Susceptibility climate	2.54	0.88
Water quality management practices	2.65	1.08
Feed input practices	2.84	1.43
Disease control input practices	2.56	0.92

Table 2
Results of hierarchical regression analyses on water quality management practices.

Step and variables	1	2	3	4
1. Farm size	−0.09†	−0.07	−0.03	0.01
Number of ponds	0.34***	0.32***	0.26***	0.21***
Stocking density *P. vannamei*	0.54***	0.55***	0.41***	0.29***
Stocking density *P. monodon*	0.10*	0.09*	0.10*	0.04
2. Cluster		0.10*	0.03	0.00
3. Public sector interactions			0.29***	0.25***
Neighbors interactions			−0.02	−0.01
Private sector interactions			0.16***	0.14**
4. Severity disease				−0.06
Severity market				0.22***
Severity climate				−0.06
Susceptibility disease				0.08
Susceptibility market				0.06
Susceptibility climate				−0.12*
ΔR^2	0.51***	0.01*	0.11***	0.05***
Corrected R^2	0.50***	0.51***	0.62***	0.65***

Note. Standardized regression coefficients are being reported.
$^{\dagger}p < .10$; $^{*}p < .05$; $^{**}p < .01$; $^{***}p < .001$.

The first analysis regressed water quality management practices on the predictor variables as described above (see Table 2). Step 1 controlled for farm characteristics; it showed that adoption of water quality management practices is significantly related to increased farming intensity of *P. vannamei* and the number of ponds in the farm, and is negatively related to farm size. Step 2 showed that clustering positively predicted water quality practices. Upon entering interactions with different actors (neighbors, private and public sector), clustering was no longer significant, suggesting that the association could be explained by interactions within farmers' networks. Specifically, interactions with both public and private sector actors positively predicted adoption of water quality practices, while those with the network's neighbors did not. Finally, in Step 4, risk perceptions were entered and showed that severity of market risk was positively associated, and susceptibility of climate risk negatively associated, with water quality-related farmers' practices

The second analysis regressed feed input practices on the predictor variables (see Table 3). As in the first regression analysis, we controlled for farm characteristics in Step 1 and this indicated that stocking density of *P. vannamei* and *P. monodon* predicted adoption of feed input practices, as well as the number of ponds and size of the farm. Then, Step 2 showed that clustering positively predicted feed input practices. Upon entering frequency of interactions with network actors, clustering significance decreased, suggesting that the association could at least be partially explained by the interactions within the farmers' network. Specifically, both frequency of interactions with public and private sector actors positively predicted feed input practices, while interactions with neighbors negatively predicted them. Finally, in Step 4, once risk perceptions were entered, clustering was no longer significant. This step further showed that severity market risk was positively associated, and severity of climate risk negatively associated, with the farmers' feed input practices.

The final regression analysis regressed disease control practices on the predictor variables (see Table 4). After controlling for farm

Table 3
Results of hierarchical regression analyses on feed input practices.

Step and variables	1	2	3	4
1. Farm size	−0.17***	−0.15**	−0.12*	−0.02
Number of ponds	0.22***	0.19***	0.15**	0.07†
Stocking density *P. vannamei*	0.62***	0.63***	0.53***	0.32***
Stocking density *P. monodon*	0.18***	0.17***	0.16***	0.05
2. Cluster		0.15**	0.10*	0.02
3. Public sector interactions			0.18***	0.13***
Neighbors interactions			−0.09*	−0.08*
Private sector interactions			0.11*	0.07*
4. Severity disease				−0.04
Severity market				0.43***
Severity climate				−0.17***
Susceptibility disease				0.06
Susceptibility market				0.07
Susceptibility climate				−0.05
ΔR^2	0.56***	0.02**	0.05***	0.15***
Corrected R^2	0.55***	0.57***	0.62***	0.77***

Note. Standardized regression coefficients are being reported.
†$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$.

Table 4
Results of hierarchical regression analyses on disease control input practices.

Step and variables	1	2	3	4
1. Farm size	−0.08	−0.04	−0.02	0.01
Number of ponds	0.19**	0.14*	0.11†	0.07
Stocking density *P. vannamei*	0.56***	0.57***	0.48***	0.43***
Stocking density *P. monodon*	0.00	−0.02	−0.03	−0.06
2. Cluster		0.20***	0.16**	0.16**
3. Public sector interactions			0.18**	0.15**
Neighbors interactions			−0.09†	−0.08†
Private sector interactions			0.07	0.04
4. Severity disease				−0.05
Severity market				0.02
Severity climate				−0.04
Susceptibility disease				0.04
Susceptibility market				0.14†
Susceptibility climate				−0.07
ΔR^2	0.40***	0.04***	0.04***	0.02
Corrected R^2	0.39***	0.43***	0.46***	0.47***

Note. Standardized regression coefficients are being reported.
†$p < .10$; * $p < .05$; ** $p < .01$; *** $p < .001$.

characteristics in Step 1, Step 2 showed that clustering positively predicted disease control practices. Upon entering interactions with actors within the farmers' networks, the importance of clustering decreased, suggesting that the association could be partially explained by interactions within a farmer's network. Specifically, public sector interactions positively predicted disease control practices. Finally, in Step 4, risk perceptions were entered but clustering remained significant. This step showed that susceptibility to market risk was marginally positively associated with disease control practices, while disease risk perceptions were not found to have any significant effects.

4.3. Mediation analyses

Mediation is indicated when the relationship between an independent variable and a dependent one runs via a mediating variable – see Fig. 1 for the research model that describes that clustering leads to the three types of farming practices via network interactions and perceptions of risk severity and risk susceptibility. Hence, mediation means that the independent variable influences one or more mediating variables (the mediators), which in turn influence the dependent variable (Baron and Kenny, 1986). Therefore, the mediator provides insight into the underlying process of the relation between the independent and the dependent variable.

The results from the bootstrap analyses for indirect effects are presented in Table 5. The mediation analysis shows that several mediators can be identified and can explain the relation between clustering and adoption of water quality management practices – as the value 0 was not included in the respective 95% confidence intervals: perception of market severity, as well as networking frequency with public and private sector actors. The other mediators tested were not found to explain the relationship between clustering and adoption of water management practices.

The second bootstrap analysis tested possible indirect pathways between clustering and feed input practices. The results showed a substantially identical pattern as the preceding analysis. That is, perception of market severity, as well as interaction frequency with public and private sector actors explain the relation between clustering and feed input practices; the other mediators were not found to explain this relationship.

Finally, the third and last bootstrap analysis tested possible indirect pathways between clustering and disease control practices. The results indicated that perception of market susceptibility perceptions and interaction frequency with public sector actors formed indirect pathways between clustering and disease control practices; the other mediators were not found to explain this relationship. Hence, this suggests that joining a cluster increases the perception of market risk susceptibility and promotes the frequency of interactions with the public sector, which in turn promotes the adoption of disease control practices.

Table 5
Bootstrap analyses of indirect relationships.

Mediator	Water quality practices				Feed input practices				Disease control input practices			
	Indirect effect	SE	95% CI for indirect effect		Indirect effect	SE	95% CI for indirect effect		Indirect effect	SE	95% CI for indirect effect	
			Lower	Upper			Lower	Upper			Lower	Upper
Public sector interactions	0.11	0.03	**0.05**	**0.19**	0.07	0.03	**0.03**	**0.14**	0.06	0.03	**0.02**	**0.13**
Neighbors interactions	0.00	0.01	−0.01	0.02	0.01	0.02	−0.03	0.05	0.00	0.01	−0.02	0.05
Private sector interactions	0.04	0.03	**0.00**	**0.11**	0.03	0.02	**0.00**	**0.08**	0.01	0.01	−0.00	0.05
Severity disease	−0.01	0.02	−0.06	0.01	−0.00	0.02	−0.06	0.01	−0.03	0.01	−0.06	0.01
Severity market	0.12	0.04	**0.05**	**0.23**	−0.01	0.08	**0.17**	**0.49**	0.01	0.04	−0.06	0.08
Severity climate	−0.01	0.02	−0.08	0.01	−0.05	0.04	−0.14	0.01	−0.01	0.02	−0.06	0.01
Susceptibility disease	0.23	0.02	−0.00	0.10	0.03	0.03	−0.01	0.10	0.01	0.02	−0.02	0.08
Susceptibility market	0.03	0.02	−0.02	0.08	0.03	0.02	−0.00	0.10	0.04	0.03	**0.00**	**0.11**
Susceptibility climate	−0.05	0.03	−0.14	−0.00	−0.03	0.03	−0.12	0.02	−0.03	0.03	−0.11	0.02

Note. SE = standard error; CI = confidence interval. Significant indirect effects ($p < .05$) are displayed in bold.

5. Discussion

Our study argues for, and demonstrates, the influence of clusters on the adoption of water management, feed inputs, and disease control practices, above and beyond the commonly described factors of adoption related to stocking density and farm infrastructure The frequency of interactions with public sector actors, and, to a somewhat lesser extent, private sector actors, could explain the differences in farming practices. In addition, the analysis shows that market risk and climate risk perception also influence adoption of the different type of practices. The underlying adoption factors are positively related to cluster membership.

The mediation analysis shows that the influence cluster farming has on adoption of farming practices runs via two underlying processes: interaction frequency with public and private sector actors and the perception of market risk, which ultimately promotes the adoption of practices. In contrast, a higher interaction frequency with neighbors has a negative effect on adopting advanced feeding practices. Finally, the results highlight the differential in effects produced by mediators according to practices, with more influence exerted on disease control practices and less so on feed and water management.

5.1. Beyond stocking density

Structural variables and stocking density are often used as predictors of farming intensity and adoption of pond management practices (Johnson et al., 2014; Engle et al., 2017). In our study we found that while the number of ponds and stocking density of *P. vannamei* were strong predictors of adoption, stocking density of *P. monodon* was not. The latter outcome could be explained by the limited number of respondents intensively farming the black tiger shrimp, resulting in a relative small sample size of respondents adopting advanced practices.

Our results demonstrate that adoption of practices can be better explained by including the factors that make up our research model. For example, hierarchical regression shows that the variance explaining adoption of feed input practices increased from 0.55 to 0.77. Similar patterns were found for water quality management and disease control practices. We therefore posit that farm characteristic and stocking density matter, but we put forward the idea that, in order to understand adoption even better, clustering should be taken into account, as well as the frequency with which farmers interact with different sources of knowledge and the risk perceptions that lead to their adoption decisions.

5.2. Do neighbors influence adoption?

In the Mekong Delta's aquaculture sector it is commonly assumed that farmers are highly influenced by their neighbors and peers (Nguyen and Ford, 2010). Remarkably, our study did not find interactions with neighbors to be influential, and in the case of feed input practices produced a negative result. The respondents indicated high levels of interactions with neighbors approaching the highest end of the scale, with little variation in the responses. Thus it is hard to detect an influence of this predictor, since all types of farmers, adopter and non-adopters alike, interact with their neighbors. Furthermore, the fact that farmers have very frequent interactions with other farmers tells us little about the quality of the interactions. For example, the interactions that farmers have with either private or public sector actors may be less frequent and the information exchanged may even be trusted less; however, farmers might perceive the actors' expertise to be more reliable than the information they receive from their peers. As noted by Aguilar-Gallegos et al. (2015), connection beyond peers is needed to facilitate adoption and heterogeneous network support innovation. In line with the literature (Isaac, 2012; Thuo et al., 2014), we show that, increasing the diversity of the information network supports technology adoption, while membership in a cluster supports this diversity. In this regard, it should also be noted that public sector actors were more influential in predicting adoption of practices than private sector actors, as these explained more variances, which happened consistently across the three different types of practices, as indicated by the results of the multiple mediation analyses.

5.3. Perception of risk and adoption

It is striking that disease risk perceptions were not found to predict any of the practices under study, including the input disease control practices – and that clusters did not influence these risk perceptions. Perhaps this is caused by a ceiling effect: farmers tend to find this highly important and therefore, as for frequency of networking with neighbors, we could not detect any effect of disease risk perception on adoption of practices.

Collective actions in farming are well known to support value chain access through different mechanisms such as contract farming and specific institutional arrangements to mitigate market risk (Hao et al., 2018; Flaten et al., 2005; Hendrikse and Bijman, 2002; Heinen and Weijland, 1989; Burger et al., 2001). A limited number of the farmer clusters' members in our sample had contracts with processing companies to purchase their production. Adoption of collective market risk mitigation mechanisms were outside of the scope of this study. However, membership in a farmer cluster had an effect on market risk perception and adoption of technology. Mediation analysis showed that membership in a farmer cluster had an indirect influence on adoption of practices by influencing risk perceptions. The perceived severity and susceptibility of market risk turned out to positively explain adoption of practices and the associations between risk perception and adoption were enhanced once farmers were members of a cluster. Here, linkages between market risk perception and adoption of practices were not obvious at first sight. However, this relation could be explained by 1) the uncertainty of shrimp's market price fluctuations, 2) the increasing cost of inputs positively influences the adoption of feed, water management and disease control practices. Farmers adopt practices with an acute perception of market risk, indicating that they are aware of market prices and production cost uncertainty. This also indicates that clusters work as hub for information (Kilelu et al., 2017a; Ha et al., 2013) by fostering the perception of market risk with access to additional sources of information. Farmer clusters diversify information and the individual farmer's knowledge sources, which influence perception of market risk and adoption of technology. As described in the introduction, we understand a farmer cluster as a small-scale farming formation oriented toward horizontal coordination and aimed at technology upgrading. We distinguished it from agri-business clusters that rather aim at vertical coordination. However, our results show that farmer clusters aggregate more than extension services, with some farmer clusters having elements of vertical coordination. This transition, which encompasses integration of vertical coordination and is geared toward realization of a full agri-business cluster may further mitigate specific types of risk that a farmer cluster with only horizontal coordination is not expected to address.

5.4. Policy and practice implications

Our study explored adoption of practices that are correlated with intensification of shrimp farming. Intensification is a double-edged sword as it can either be regarded a panacea or carry negative connotations, depending upon what exactly is to be intensified in agriculture. In past years, policies designed by the Vietnamese authorities promoted the transition of extensive shrimp farms toward intensification (Ha, 2012) and water management at the landscape level (Dung et al., 2017; World Bank, 2014). Supporting the development of farmer clusters, which are based on voluntary membership and driven by local leaders, is part of the policy to support transition of the shrimp aquaculture sector. While stimulating farmer clusters thus can foster intensification, it has been observed that this policy approach nonetheless has had limited success in Vietnam regarding the upgrading of production and producers' access to the global value chain and standard certification (Ha et al., 2013). Ha et al. (2013) identified some key constraints to the transition toward more vertical coordination in farmer clusters (such as accessibility and spatial distribution of the farms as well as the social organization of the farmers), concluding that the transition might not be effective in all shrimp farming areas of the Mekong Delta. This reflects on Matous' (2015) conclusion that farmer groups are not all equal and that the diversity of their structure and composition affects the outcomes of the farmer cluster.

Notwithstanding these observations on the apparent limited success of existing clustering policies, the current study suggests that the horizontal type of farmer cluster is a promising avenue for fostering interactions between farmers and other key actors in aquaculture. It shapes the formation of specific aqua-related risk perceptions, and subsequent practice adoption. It also shows that farmer clusters help the transition toward more vertical coordination and can support integration of smallholders within the value chain (echoing Kilelu et al., 2017a; Van der Lee et al., 2018). Farmer clusters are thus an interesting entry point for forming more vertical clusters in due time, and our study offers some key insights that policy makers can take into account in formulating more effective policies, reinforcing some recent insights reported by the literature on farmer clustering.

A first policy and practice implication is, as our study indicates and has also been noted by Bottema et al. (2018), that in order to address on-farm risks, farmer clusters in shrimp farming should be organized around homogenized environmental risk perception (i.e., climate, water quality). Organizing farmers around particular shared (perceived) risks, may energize the cluster in order to mitigate these risks. As such, these shared risks may serve as key identifiers for forming for active and successful farming clusters. This can strengthen the engagement of farmers in the cluster and may foster better integration within the value chain.

A second policy and practice implication is that a spatial or area-based approach (following Aguilar-Manjarrez et al., 2017) to clustering is an entry point for supporting the development of those farmer clusters in the Mekong Delta. As noted by Ha et al., 2013, past approaches were planned without considering local diversity of production systems, infrastructure, and social dimensions. When promoting farmer clusters, policy makers and practitioners such as NGOs should therefore take into consideration both social linkages as well as spatial dimensions, with the aim of forming farmer clusters that are homogeneous in terms of needs and requirements of its members, and also levels of risk perception.

In view of the above, this thus points at the importance of careful selection of farmers to be included in the cluster instead of seeing the cluster as a one-size-fits-all for all farmers.

5.5. Limitations and areas of future research

Social interactions in farmers groups are significant in explaining behaviors and change of practices (Solano et al., 2003; Spielman et al., 2011). Our study does not encompass in its unit of analysis the whole cluster dynamics at the level of farmer collectives and the role of other cluster players, while the nested structure of clusters may have an effect on the individual level of farmers (Cheong, 2012). Focusing only on the individual farm level does not allow for a full appraisal of possible higher level interactions in clusters, and following Matous (2015) future studies would need to take this into account and expand the analytical model used in this study.

Our analysis at the individual farm level shows that farmer clusters, by fostering linkages and facilitating interactions between different knowledge sources, can promote adoption of practices toward intensification. In our research, we investigated the role of the *frequency* of interactions between farmers and actors within the same network. Our study did not investigate trust, nor did it look into the quality of the training and advices provided by the different sources of knowledge. Therefore, perceiving farmer clusters' membership as an efficient tool to foster adoption of risk-mitigating farming practices, would suggest the specific message, conveyed by both extension services and the private sector, to be central to steering the sector toward sustainable intensification. In order to better understand these dynamics, future research should focus on the *quality* of the interactions, such as whether farmers trust or think that the various actors have relevant expertise in their respective networks..

6. Conclusion

This study explored the adoption of aquaculture farming practices. We use the case of shrimp farming in the Mekong Delta to investigate – beyond the influence of farm structure and farming intensity – underlying drivers of adoption of feed, water management and disease control practices. We disentangled the influence that membership in farmer clusters has on perception of different types of risk and that frequency of interaction with diverse knowledge sources has on adoption of practices. We found that these drivers also play a significant role in adoption of practices in addition to farm characteristics.

We showed that cluster membership has a significant effect on adoption of all three types of practices under study. Analyzing the interactions with different knowledge sources shows that all types of farmers have a high interaction frequency with neighbors while membership in a cluster facilitates interactions with other sources of knowledge. We also showed that the clusters under investigation have characteristics that encompass more than traditional farmer clusters and could be intermediary types, with elements of agri-business clusters and vertical coordination. Hence, some of the clusters studied are morphing from farmer clusters to agri-business clusters. Farmer clusters and their intermediate form promote frequency of interactions with public and private sector actors and enhance the farmer's perception of market-related risk, which ultimately influences adoption of advanced practices. Even if farmer clusters differ in their organizations and activities, the most common feature and effect is their positive influence on access to diversified sources of knowledge that influence farmers' perceptions of risk and adoption of practices.

Farmer clusters, as they transition into agri-business clusters, are avenues to support the farmers' knowledge transfer and learning in such a way that is more efficient in this particular context, where small-scale farmers dominate the landscape. To more effectively deploy a cluster approach a key policy and practice implication is to take into consideration local idiosyncrasies defined by their social interactions, risk perception and spatial dimensions in order to better facilitate local linkages between farms (horizontal coordination) and a better integration with the value chain (vertical coordination).

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.agsy.2019.02.011.

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