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The cluster panacea? An evaluation of three interventions in shrimp value chains in Bangladesh

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Abstract

Clustering farming has often been proposed as an effective way to overcome the significant transactions costs faced by downstream buyers in interacting and negotiating with many small farmers, while making it easier for extension workers and governments to dispense advice, provide upstream services and inputs. In this study, we evaluate the impact of a set of three initiatives in Bangladesh, implemented by a government department, a private sector processing firm and a not-for-profit industrial advocacy body, all involving clustering contiguous shrimp farm ponds to enable group certification necessary for global market access. We implement a canonical difference-in-differences model using two rounds of surveys of a sample of over 1,222 farmers in 2023 and 2024 to assess the impacts on pond management practices, net profits and any unintended impacts on food security and dietary diversity. Our results suggest that the cluster interventions had impressive impacts on adoption of better farm management practices. However, these do not appear to translate into significant gains in net profits, perhaps because these interventions are still relatively new. Further, it appears that cluster farmers pay a penalty on account of a shift to more intensive cultivation, represented by a loss in species diversity and lower incomes from fish and vegetables. We find that there are no significant spillover effects as yet on shrimp farmers in the same village as the clusters. This study reflects critically on the efficacy of clustering that is presumed to enhance access to global markets.

Keywords: cluster, adjustment costs, Difference in differences (DID), intention to treat (ITT) estimates, heterogeneity, bundled, shrimp, Bangladesh

JEL : Q01, Q13, Q22, Q18, R12, R3

1. Introduction

Clustering economic activity for development has often been identified as an effective policy intervention and the theoretical literature within economics highlights the economic rationale for agglomeration. Clusters are spatial aggregations of farms or businesses producing the same or related goods or services, that may emerge either spontaneously or because of an intervention (Belton et al. 2024). While the precise definition of clusters varies and may include organizational forms such as cooperatives and collectives, a shared feature is spatial concentration of these activities. In farming, clusters can be commodity-based where farmers grow the same commodity or an area-based where farmers form clusters based on their contiguity; in most farming clusters, farmers combine their production and sell it in higher volumes, often to a common buyer. The chief purported benefits of clustering are the reduction in transactions costs faced by downstream buyers in interacting and negotiating with many small farmers, while making it easier for extension workers and governments to dispense advice, provide upstream services and inputs. Clusters can also foster innovation, enable risk sharing via greater coordination and upgrading quality and standardization, often a prerequisite for accessing modern value chains (Oakeshott 2016, Montiflor et al. 2008). Clustering as an approach has the potential to contribute to economic development of rural areas by compounding the existing strengths of local producing communities (Belton et al. 2024, FAO 2010, Oakeshott 2016). Cluster-based interventions reflect a range of objectives. These include cooperatives, group-based certification, and rural development programs such as Japan's One Village One Product (OVOP) and Thailand's One Tambon One Product (OTOP) schemes.

Yet, despite the popularity of cluster-based approaches in agriculture, there continues to exist limited evidence on its impacts. Clusters in agriculture have been found to increase member incomes (for example, Rola-Rubzen et al. 2013 in the Philippines, Fischer and Qaim 2012 for cooperatives in Kenya), marketing volumes and extent of commercialization (Endalew et al. 2024 for teff in Ethiopia, Dureti et al. 2023), technical efficiency (Goni et al. 2023 for rice in Nigeria) and adoption of new technologies. Existing evidence notes however that these benefits may be heterogenous. While some find no difference in benefits for those who join clusters sooner rather than later, significant differences seem to exist based on age of the farmer and land size and endowments (Barham and Chitemi 2009 in Tanzania). Extension agents who are crucial for organizing and managing clusters also matter for cluster performance (Hassan et al. 2017 for cocoa clusters in Malaysia). Most studies note that clusters themselves might be exclusionary, selecting certain kinds of farmers over others (Dureti and Tabe Ojong 2024 for Ethiopia, Fischer and Qaim 2012 for Kenya). Motivations for joining clusters can also vary across gender (Kariuki 2005 for Kenya) where men join clusters for accessing markets and women to build household assets. Further, clusters might be promoted in areas that have specific locational advantages. Thus, clusters may direct benefits to some areas and groups of farmers rather than others.

There are also serious questions about the ability of managed or organized clusters to survive (Murray-Prior et al. 2012, World Bank 2013). Cluster-based development has been successful where governments facilitate infrastructure and provide services to support existing clusters, often leading to spillover and expansion of these clusters to wider areas over time (Abdelaziz et al. 2021). Managed or organized clusters often implode once external support ends. Clusters might also leave members vulnerable in the face of covariate shocks that affect multiple players all at once, leading to competition for scarce resources rather than cooperation (Kabir et al. 2023a).

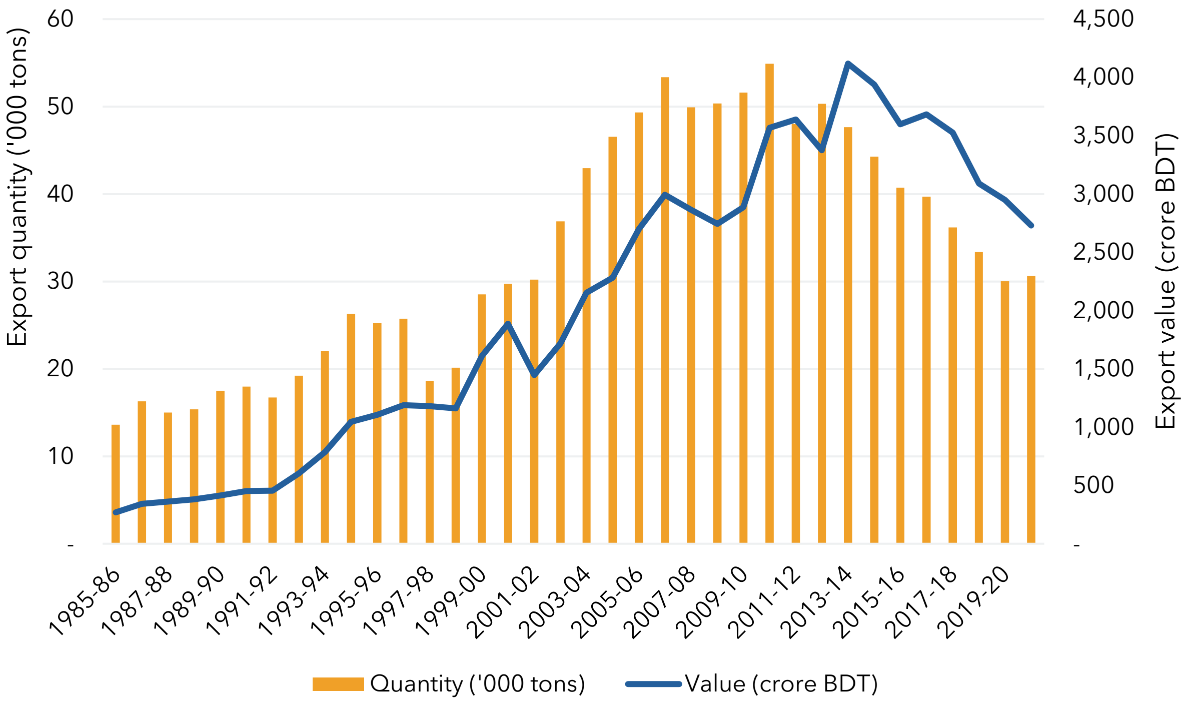
In this study, we examine a range of these questions in connection with three cluster interventions in Bangladesh, each organized by a government department, a not-for-profit and a private agribusiness company, respectively, all aimed at organizing shrimp farmers with contiguous ponds into clusters. Using two rounds of data of 1222 cluster and non-cluster farmers from 68 distinct clusters spread over 128 villages, before and after the intervention, we use a canonical Difference in Differences (DID) approach to uncover plausibly causal short-term impacts of clusters on member net profits, and first order impact on adoption of improved pond management practices. We also attempt to isolate the pathways through which such impacts, if any, obtain. We go further than most studies to investigate the tradeoffs that cluster members might face and adjustments they make in the activity portfolio and any unintended consequences for dietary diversity and food security. We also test for the presence of spillover effects, on whether farmers who are not cluster members but located within communities that have cluster adopt practices and benefit from the intervention.

This study is organized as follows. In Section 2 below, we describe the context and rationale for the cluster-based interventions and describe these interventions in some detail. In Sections 3,4 and 5, we outline our key research questions, outcomes of interest, empirical strategy and data collection and sampling strategies. In Sections 7 and 8, we discuss the results. Section 9 explores the impacts further and aims to identify the key drivers of impacts. Section 10 concludes the discussion.

2. The cluster interventions

There is currently consensus that Bangladesh has significant potential in exporting shrimp to global markets, but that this potential remains unrealized on account of the pattern and nature of shrimp farming in the country (Kabir et al. 2023b, van der Pijl 2014, van der Pijl and van Duijn 2012). Indeed, after years of rapid growth in shrimp exports, in volume and value, the 2010s have seen significant reversals (Figure 1). Most shrimp exports from Bangladesh are used by the food service and niche ethnic markets in Europe. The recent decline in exports has been driven in part by competition from other exporting countries, but also on account of a shift among farmers to producing greater quantities of less risky fish for the burgeoning domestic market (Kabir et al. 2023b, Belton and Ali 2022, Belton et al. 2011). Shrimp farming in Bangladesh involves extensive polyculture on small farms, that often combine growing rice in the shallow ponds (ghers) and vegetables on the perimeters. There is limited use of good quality seed (specific pathogen-free [SPF] and polymerase chain reaction [PCR]-tested post-larvae [PL]), and most pond infrastructure is in poor condition and few farmers adopt scientific pond management, and biosecurity practices. These result in poor yields and the processing sector relies overwhelmingly on intermediaries to aggregate and handle produce. contributing to underutilization of processing capacity. This pattern of shrimp cultivation also poses formidable challenges to traceability and certification; these latter are increasingly surfacing as requirements to access global markets such as the European Union (EU), and higher value market segments such as supermarkets.

Figure 1: Annual frozen shrimp and prawn exports from Bangladesh, 1985-86 to 2020-21



Source: Kabir et al. (2023b) based on data from Yearbook of Fisheries Statistics of Bangladesh, DoF, several years.
Note: Quantities and values are reported by fiscal year. In Bangladesh, the fiscal year runs from July to June. In 2020, the nominal exchange rate was $1=84.9 BDT.

To address these constraints, a range of innovative efforts have emerged recently in Bangladesh that aim to aggregate farmers and their production through clusters, with coordinated and simultaneous stocking and harvesting of shrimp within the cluster, disintermediation through direct sales to processors, increasing volumes of shrimp available for processing, and implementation traceability systems that may serve as an entry point for the subsequent introduction of third-party certification. Our research focuses on three specific interventions, implemented by: (1) the Department of Fisheries, Government of Bangladesh (under the World Bank-funded Sustainable Coastal and Marine Fisheries Project [SCMFP]), henceforth DoF; (2) ACI Agrolink Ltd., henceforth ACI; and (3) the Bangladesh Shrimp and Fish Foundation (BSFF).[1] These three represent diverse actors, including government, private sector processor cum input firm, and industry advocacy body. Supplementary Appendix 1 provides a detailed account of the three models, but we summarize the salient features below.

All three seek to organize shrimp farmers with contiguous ponds into clusters. Farmers with pond sizes less than 1 hectare were chosen, and approximately 25 such farmers with contiguous ponds were organized into a group. All three programs include training on best practices, transfer of inputs and technology to farmers. Specifically, farmers are persuaded to deepen their ponds to reduce water temperature variability that can trigger disease outbreaks and facilitate increased stocking densities of SPF post-larve (henceforth "SPF-PL"). Farmers were also encouraged to stock just once and coordinate stocking and harvesting to have aggregable volumes. In the DoF model, these were preconditions to participate. DoF identifies clusters whose members adhere to these norms and deems them to be "graduated clusters". Such clusters receive financial aid that matches individual member contributions. In this study, we differentiate them from non-graduated clusters. Farmers were also encouraged to grow bagda (black tiger shrimp, *Penaeus monodon*) rather than golda (giant freshwater prawn, *Macrobrachium rosenbergii*) since the former is typically processed for export. Farmers were typically encouraged to ensure biosecurity of ponds by giving up growing vegetables on the perimeters and rice in the shallow ponds.

Notwithstanding these differences, all cluster interventions aim to supplant a traditional extensive production system with monoculture, intensive system, to varying degrees. The premise of these interventions is that clustering of shrimp farmers in Bangladesh establish a basis for enabling certification and therefore access to global retail markets in a context where such access in challenging at best. As is clear from the above, the "cluster intervention" we refer to throughout this study therefore comprises a bundle of practices. In this study, we make two analytical choices: first, we analyze the impact of the cluster intervention bundle and not of its individual components. However, we later attempt to investigate the relative contribution of the different individual components to unpack our results, although our causal interpretation is not valid when we analyze the individual components of the cluster intervention. Second, we pool the three interventions for the main analysis to assess the impacts of clustering, so that it is agnostic to the cluster organizer. This is because the scale of two of the three interventions was too small to analyze them separately.

The interventions we study are in many ways typical of cluster farming initiatives in shrimp aquaculture globally. Most interventions of this kind from other contexts focus heavily on best management practices (BMPs), since it is easier to implement in group-based structures for support organizations such as private

[1] ACI Agrolink is a seafood processing firm that is part of a Bangladeshi conglomerate, whose business interests include fish feed, rice milling and so on. ACI Agrolink Limited operates a shrimp processing plant to process and export 100% export quality frozen shrimps. Their shrimp export business started in 2019. BSFF is a private nonprofit for research, advocacy and targeted actions in the fisheries sector, aquaculture and shrimp value chains. Registered in 2003 under Trust Act 1882 and with the Social Welfare Directorate in 2008, it has been functioning since June 2003.

sector organizations, NGOs, and government organizations. Existing evidence suggests that clusters often achieve their goals, increasing uptake and adoption of environmentally sustainable practice and food safety, i.e. reducing use of harmful chemicals, discharge of sediments (Umesh et al. 2010, for example, in India). Clusters may also increase the technical efficiency of farms and profitability of farming via reduction in the cost of production, increased profits, and reduction of disease risks (Bhattacharya 2010, Umesh et al. 2010). Our research adds to this body of works.

3. Research questions and outcomes of interest

A first question of interest is whether cluster formation leads to adoption of better pond management practices, some of which are warranted/ mandated by the program. We identify 20 distinct but related practices, including adapting pond infrastructure, biosecurity practices such as netting and fencing, maintenance of water quality, species selection, feed, stocking and harvesting practices. Despite differences, all three interventions aimed at influencing some of these to prepare farmers for certification, eventually. These indicators therefore provide evidence as to whether cluster interventions had the intended effect of promoting specific shrimp farming practices that prepare farmers for certification.

Our ultimate outcome of interest is, however, net profits per acre of pond, measured in terms of revenue net of paid out costs per acre of pond (See Appendix Table 1 for details on definition and measurement). Our key question of interest is whether cluster participation leads to higher net profit per acre of pond for farmers. We track this outcome since all the cluster interventions in this study purportedly promote small farmers' access to global markets that has the potential to increase farmer incomes. It is worth noting here that we only assess impacts after a single season of intervention; this may be limited if it takes time for farmers to adopt the recommended practices.

Apart from tracking profitability, we also track some pathway outcomes that represent the costs of transition from more traditional ways of shrimp farming to the cluster model. As evident from the description of the intervention, farmers who belong to clusters, make several adjustments to their farming practices including a potential shift from polyculture to monoculture, in choice of species, in supplementary activities such as vegetable and rice cultivation and financial investments in pond infrastructure. To understand the impacts on net incomes, we track impacts on production costs, shrimp mortality, incomes from selling shrimp, fish and other crops, pond productivity (for shrimp, fish, and both), and farmed species diversification in terms of the Herfindahl-Hirschman Index (HHI). Our secondary outcomes include food security reported as the Household Food Insecurity and Access Score (HFIAS), dietary diversity as per the Household Dietary Diversity Score (HDDS). Appendix Table 1 provides a detailed list of the outcome measures and how these are computed.

We evaluate these outcomes for different subsets of farmers – cluster farmers, farmer-members of graduated farmers and for those who do not participate in clusters but are located in villages that have these clusters. This last group of farmers might potentially benefit from spillover effects if cluster intervention within a community foster learning and adoption of better pond management practices in the wider community.

4. Empirical strategy

An ideal approach to credibly uncover the causal impact of participation in clusters would be to randomly assign shrimp farmers to clusters and then measure outcomes of interest. However, in the context of our study, this was infeasible as each implementation partner had already identified potential villages and farmers to work with. Like most other research on clusters, we therefore rely on quasi-experimental approaches. Thus far, research on agricultural clusters has relied overwhelmingly on simple comparisons between cluster members and nonmembers from cross-sectional surveys. Most researchers have turned to matching techniques on observable characteristics to tackle selection bias. In contrast, we take advantage of a panel dataset that offers us an opportunity to tackle time invariant unobservable characteristics and time varying characteristics that may drive selection bias.

We use a canonical Difference in Differences (DID) design to identify causal impacts of cluster participation, relying on a rich set of controls to account for potential sources of selection bias that thwart identification. The DID approach essentially measures changes in outcomes of interest among participating farmers linked to the cluster and comparing them to the changes experienced by those who are not engaged with any of the implementation partners, controlling for any other drivers of these differences.

To assess whether the treatment and comparison groups are comparable, we first examine key differences between cluster and non-cluster farmers within our sample using preintervention Baseline Survey data and run the following probit model:

$$P(C_{iv} = 1) = \alpha + \emptyset \boldsymbol{X}_i + \gamma \boldsymbol{Z}_v + e_i \quad (1)$$

where C_{iv} takes on the value 1 if the individual is member of a cluster, 0 otherwise, and X_i is a vector of individual and household characteristics and Z_{iv} is a vector of community and village characteristics where farmer *i* is located. Z_{iv} tests for placement effects of these clusters, noting that managed clusters can be targeted to areas with specific locational characteristics. We include in Z_{iv} include size of the village in terms of number of households, of aquaculture ponds and of shrimp farmers, whether a village is located in a polder, whether the village has been vulnerable to climate shocks and village infrastructure both socioeconomic and specifically relating to fish and shrimp input and marketing facilities. X_i includes household size, household dependency ratio, casual labor, education (self and household head), sex, age (self and household head), years of experience in shrimp farming, religion, landholding size, and asset ownership quintiles. Covariates that are statistically significant indicate systematic differences between cluster and non-cluster members either based on location or community characteristic or individual and household characteristics, flagging potential selection bias in evaluating impacts. We use these to populate our DID model, controlling for both preexisting observable differences as well as controlling for time varying characteristics that are potentially the source of selection bias.

We estimate causal effects of cluster participation using the canonical DID model below, with two groups (a treated, i.e. cluster and control, i.e., non-cluster) and two periods of time (before and after the intervention).

$$Outcome_{ivt} = \beta_0 + \beta_1 Year + \beta_2 Cluster + \beta_3 Cluster \times Year + \emptyset \boldsymbol{X}_{it} + \gamma_1 \boldsymbol{Z}_{vt} + \gamma_2 \boldsymbol{Z}_v + \epsilon_v \quad (2)$$

where $Outcome_{it}$ is an outcome of farmer i, time t. $Cluster$ is a binary indicator for whether farmer i belongs to a cluster and is our causal variable of interest. $Year$ refers to preintervention and post intervention, and $\boldsymbol{X}_{it}$ is a vector of timevarying pond characteristics. These pond characteristics include the pond area, its tenure status, distance from the nearest water source, aerator use, and flooding incidence. We control for two sets of community or village characteristics $\boldsymbol{Z}_{vt}$ and $\boldsymbol{Z}_{v}$, time varying and time invariant characteristics respectively. Standard errors are clustered at the cluster level (this includes the village with the clusters and the comparison village in the sample) and we include fixed effects at the upazila (sub-district) level.

As elaborated already, our choice of variables is guided primarily by our analysis on selectivity, and we ensure that we include any characteristic that is potentially a source of selection bias based on time-invariant features. Including time varying characteristics at the household, pond and community level, such as weather shocks, ensures that the change we observe in the treatment groups is not a consequence of confounding factors (See Appendix Table 1 for a list of variables). DID takes care of time invariant differences but not time varying differences. This is therefore our preferred specification[2].

The primary coefficient of interest is β_3, which captures the causal effects of clusters reflecting an Intention to Treat (ITT) effect. We cluster standard errors at the upazila level where shared unobservable characteristics might influence net profits. Our analysis is powered to detect significant slope coefficient for pooled analysis (See Supplementary Appendix 2). We therefore focus on a pooled analysis from all three cluster interventions.

A key assumption of the DID approach to identification is that cluster and non-cluster farmers share common trends in outcomes, before the intervention. In the context of this evaluation, this assumption implies that trend in net profit per acre of pond was similar for both the groups; if this were true, in the absence of treatment the cluster farmers would have shared parallel trends with non-cluster farmers. We test this assumption and find that this holds for virtually all the outcome variables.

4.1. Nature of comparisons

We implement regressions presented in Model (2) for a range of outcome variables described already, for different subgroups. First, we compare all cluster farmers with all non-cluster farmers. This identifies the overall impact of cluster participation. Second, we focus on farmers belonging to DoF's "graduated" clusters, that ostensibly followed the mandated practices and benefitted from a matching grant and input subsidies. We compare these "graduated" cluster farmers with all non-cluster farmers. This identifies impacts for a sub-group that represented better implementation/adoption. Third, we drop "graduated" cluster farmers from the treated group and compare just the non-graduated cluster farmers with all non-cluster farmers. We do this to uncover any differences between the strength of impacts when clusters follow the mandated or recommended practices more closely and when they do not. Note that in each of these three versions, the group of comparison farmers remains the same and we only vary the treated group. Fourth, and finally, to investigate whether there are any spillover effects of cluster farming on non-cluster farmers within the cluster villages, we compare the subsample of non-cluster farmers within the same village as cluster farmers with those non-cluster farmers residing in neighboring/adjacent villages, which do not have any cluster. Our sampling approach, described in detail below, and power calculations were designed specifically to accommodate such an assessment.

[2] When controlling for village level variables, we note that some villages have more than one cluster. 86 sample cluster farmers are from villages that have another cluster from our sample.

4.2. Heterogeneity, bundling of interventions and short-term impacts

Our research effort comes with caveats. First, our causal variable of interest is cluster membership, a binary variable that carries the value 1 if a farmer belongs to a cluster and 0 otherwise. Yet, as elaborated already, each model bundles several components – some are mandated practices and others that farmers may have been encouraged to adopt. As such, our study design cannot credibly isolate the effect of each component of the intervention (quasi) experimentally. We are therefore only able to comment on the impact of clusters as a whole and explore the possible contribution of each non-experimentally. In Section 8 we attempt to redress this lacuna by estimating the association of different individual components with our outcomes of interest.

Second, there is also significant heterogeneity in treatment, i.e., each cluster organizer likely emphasized different practices. In other words, belonging to a cluster implies very different things across the three models. In impact evaluation terms, treatment is heterogenous and varies across the three cluster models. We treat these as three aggregable models of clusters that permit a pooled analysis. The scale of intervention for two of the three models (BSFF and ACI Pvt. Ltd.) is too small for us to be able to explore the differential impacts of the three models. We are therefore able identify impacts precisely for only one of the three models – the DoF. In Supplementary Appendix 3, we analyze the sample separately for DoF farmers.

Third, our assessment of impacts focuses on the short-term, for just one season after the intervention. In many contexts, interventions might take longer to translate into adoption. The results of this work must therefore be interpreted as short-term impacts of cluster interventions.

Fourth, we estimated the sample size for the evaluation to be able to precisely identify the main outcome of interest, i.e. net profit per acre. While we explore the pathways and tradeoffs associated with these outcomes, power calculations for each of these pathway indicators could not be conducted ex ante for want of pertinent data.

5. Sampling and data collection

5.1. Survey rounds and instruments

Our study is based on two rounds of data collection: (1) a Baseline (conducted in November 2023), where we captured key baseline characteristics and recall data for the crop year 2022 and crop year 2021, and (2) an Endline in May-June 2024 that allowed us to capture information on up to two crops.

In each round, we trained teams of enumerators who visited each selected farmer in person and conducted a detailed interview via a structured farmer questionnaire to capture the information relevant to the outcomes of interest. The instruments also included some questions on subjective perceptions of the challenges and enablers associated with shrimp farming. Apart from a structured interview with farmers, we administered a community survey to capture the broader context of shrimp farming in the village selecting key informants in the village. We also administered a cluster level questionnaire that aimed to record key features of the cluster, including its age, profile of members, extent of formalization and activities. We obtained both a local Institutional Review Board approval from the University of Dhaka and one from the International Food Policy Research Institute (IFPRI).[3]

5.2. Sampling design

The study was conducted among shrimp farmers located across 16 upazilas[4] (subdistricts) in the southern districts of Khulna, Bagerhat, and Satkhira, corresponding to the locations of the cluster initiatives (Figure 2). Over two rounds, we surveyed 1,222 farmers, of whom 622 were in the "treatment" and 600 in the comparison groups straddling the three models (i.e., DoF, BSFF, or ACI clusters) (Table 1). The attrition rate was 0.98% and we use a balanced panel of 1210 farmers. The two comparison groups are (a) non-cluster farmers located within the same village or (b) in a neighboring/adjacent village, who currently have no relationship with the implementation partners.

Treated farmers were randomly selected from a list of participating farmers who stocked their pond under the intervention in the 2023 production cycle. In the case of DoF farmers, we employed a two-stage simple random sampling design: we first randomly sampled 60 clusters from a total list of 300 registered clusters[5], obtained from the SCMFP project. From each sampled cluster, we then randomly sampled seven cluster farmers. If some the sampled farmers had joined but then "dropped out" of their respective cluster initiative, we treat these farmers as "cluster" farmers but also drew replacement farmers from the list of cluster farmers. We therefore interviewed a total of 444 DoF cluster farmers.

In the case of BSFF and ACI farmers, we sampled all farmers within eight functioning clusters (four BSFF and ACI clusters each, respectively). In the case of BSFF clusters, there were 20 farmers per cluster, for a total of 80 farmers; and 25 farmers per cluster in the case of ACI clusters for a total of 98 farmers[6].

As discussed earlier to be able to identify spillovers, we choose two groups of non-cluster farmers, those located in the same village as cluster farmers, and those located in a neighboring/adjacent village. This

[3] The IRB application approval numbers from IFPRI for the baseline and endline are DSG230837 and DSG230837M, respectively and for the University of Dhaka, 322024 and 472023 respectively.
[4] The number of upazilas in our sample is essentially a function of sampling design, where the probability of an upazila being in our sample is dependent on the distribution of bagda shrimp farming clusters across upazilas in the three districts under study.
[5] Of the 300 DoF clusters, 181 produced bagda shrimp (whether in mono or polyculture), while 119 were golda or golda/carp mixed culture clusters. As this study focuses on global value chains, the 60 clusters were drawn from the 181 bagda production clusters.
[6] Two farmers were ineligible for the study.

allowed us to account for spillover effects of cluster farming practices that may have been adopted by farmers in the same village, while also accounting for "default" practices in neighboring villages. Thus, each cluster has an associated set of non-cluster farmers to ensure that the non-cluster farmers are geographically distributed.

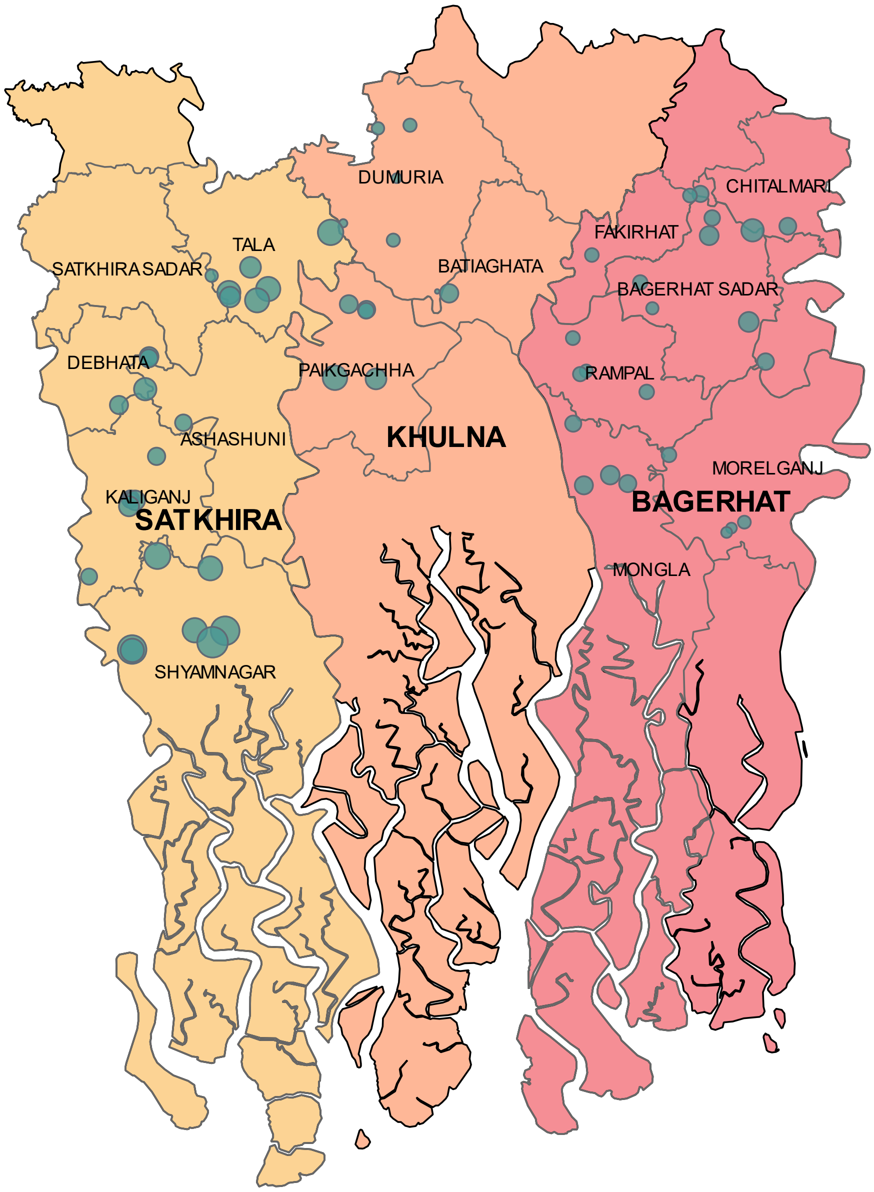
In the case of DoF clusters, we first listed all non-cluster shrimp farmers in the same village and in an adjacent village, and then randomly sampled three such farmers from the same village, and four farmers from the adjacent village. In the case of BSFF clusters, we followed the same process and randomly sampled eight farmers from the same village as cluster farmers, and 12 farmers from the adjacent village. For ACI clusters, we did the same and sampled 12 farmers from the same village, and 13 from the adjacent village. Given that DoF, ACI and BSFF had carefully selected farmers to work with, we chose comparison group farmers who "look" very similar to those who the three implementation partners currently work with. Table 1 provides a detailed breakup of the sample.

Table 1: Farm household sample distribution by district

Cluster organizer	**Household sample type**	**Number of sampled households**			
		Bagerhat	**Khulna**	**Satkhira**	**Total**
DoF	Cluster	166	96	182	**444**
	Non-cluster (same village)	69	36	75	**180**
	Non-cluster (adjacent village)	92	48	100	**240**
BSFF	Cluster		80		**80**
	Non-cluster (same village)		32		**32**
	Non-cluster (adjacent village)		48		**48**
ACI	Cluster			98	**98**
	Non-cluster (same village)			42	**42**
	Non-cluster (adjacent village)			58	**58**
Total	**Cluster**	**166**	**176**	**280**	**622**
	Non-cluster (same village)	**69**	**68**	**117**	**254**
	Non-cluster (adjacent village)	**92**	**96**	**158**	**346**
	Total	**327**	**340**	**555**	**1,222**

Source: Authors.
Note: DoF = Department of Fisheries. BSFF = Bangladesh Shrimp and Fish Foundation. ACI = ACI Agrolink Ltd.

Figure 2: Map of the study area and sample sites



Source: Authors.
Note: Sampled clusters are shown as circles, with size proportional to their overall annual bagda shrimp production.

6. Descriptive characteristics

6.1. A profile of the clusters

In this section, we draw on baseline data on clusters to characterize them, recalling that 60 out of the 68 clusters study are from the DoF project (Table 2). The mean size of the 68 clusters studies are 25 farmers, with an average pond size of 2266 decimals (or less than an acre/member). These are therefore small farmers, somewhat reflecting the average size of ponds in the region. Most clusters are registered entities (91%), have a bank account (90%) and elect a representative to coordinate activities, but only 19% have an office space. Clusters tend to meet regularly to coordinate their activities and among the 68 clusters studies, they met at least 8 times in 2023, with 89% of the clusters reporting that they meet at least once a month. These clusters tend to be dominated by men with an average of about 5 women members, out of the 25 members in a cluster, with a standard deviation of 4.7 suggesting differences in the proportion of women members in these clusters. Not all clusters collect fees for their operation and these fees, by all accounts, were not mandated by the cluster organizers.

Clusters exhibit a fair degree of homophily – 87% and 79% of them noted that members are mostly from the same religion or have shared ethnicity, clan or kinship ties respectively. Only 4% of the clusters, however, seem to have members with similar education levels so that members of a specific cluster likely have varying levels of educational attainment.

Clusters seem to operate mainly independently, with just 15 and 4% nothing that frequently work or interact with other groups within or outside the village respectively. These clusters were not formed based on preexisting groups. Given the short time between our Baseline and Endline, most clusters did not see attrition over this period.

What does cluster membership entail in terms of shrimp operations and pond management practices? We already described the interventions briefly, but we also asked farmers and representatives of the clusters what it meant to belong to a cluster. Across cluster organizers, training was an important component, and each cluster had received intensive training on 36 occasions in the two years preceding the survey on both shrimp farming as well as on operations of the cluster itself. None of the clusters had marketing contracts with processors at the time of the survey. But a few had such arrangements with input suppliers, with variation across cluster organizers. DoF enabled farmers to access government programs and subsidies, whereas BSFF and ACI did not. Crucially, these clusters facilitated access to specific inputs including SPFPL, feed and so on. As part of our survey, we asked cluster members in our sample to list the set of practices that were recommended and asked to note if it was mandatory or just encouraged to understand the components of the intervention. The findings are largely consistent with the understanding of clusters as reported by the cluster organizers (Figure 3). At the core of the intervention was contiguous ponds, in which farmers would stock SPF-PL as far as possible and coordinate stocking and harvesting with other members. These ponds would have to be deepened to limit mortality associated with shallow ponds. Installing blue fencing and bird nets to increase biosecurity were also identified by a majority of the sample as mandatory practices. Credit and insurance were not part of the bundle of inputs that the organizer provided.

As part of our survey, we asked farmers to share their experience farming as a cluster. Most farmers value participating in the cluster programs and value, in particular, the training and learning opportunities that the cluster enabled. For example, all the farmers in the DoF program, reported that they were happy with the training provided by the Department of Fisheries (DoF). At the same time, farmers found it difficult to adopt all the practices and it is not always easy to secure cooperation of all members of the cluster.

The interviews suggest that the experience of cluster farming was mixed among farmers, in part because the implementation of the initiative was not uniform across regions. Farmers who complied with conditions set by DoF were eligible to receive grants. Consequently, they could follow most of the pond management practices prescribed in training without major financial hardship. As a result of the cluster farming intervention, farmers spontaneously adopted some practices. The most frequently adopted practices seemed to be the construction of wider embankments, increasing pond depth, pond water and soil management, bolstering biosecurity measures, use of formulated feeds, applying prebiotics and probiotics, stocking fingerlings using nursing points, and coordinated harvesting and marketing. The allotted grant was distributed among farmers as in-kind support, which included feed, probiotics, prebiotics, lime, bleaching powder, molasses, yeast powder.

Many farmers experienced a high variation in production due to inconsistent implementation of the initiative and delayed provision of financial and in-kind support, a point worth bearing in mind as we interpret the results of the evaluation. A noticeable number of farmers did not adopt all pond management practices. The primary reason for not adopting all pond management practices was financial constraints. These financial challenges became more acute when farmers failed to fulfill major conditions, such as deepening the pond and ensuring the biosecurity of all contiguous ponds in the cluster, which were necessary to qualify for financial grants. Since many farmers could not comply with these conditions, they did not receive grants to implement other pond management practices. Deepening the pond was particularly challenging for two reasons. First, the use of excavators, as required by the Department of Fisheries (DOF), was very costly. Second, farmers with leased *ghers* could not negotiate longer contracts with landowners due to the high cost of advance payments, which typically involved five years of fees upfront. The second condition, ensuring biosecurity, was not met due to coordination issues among cluster farmers. In addition to financial challenges, some clusters faced availability issues that prevented them from adopting SPF fingerlings. The lack of necessary equipment and unfamiliarity with new practices further complicated efforts to maintain biosecurity and hygiene or conduct regular water tests.

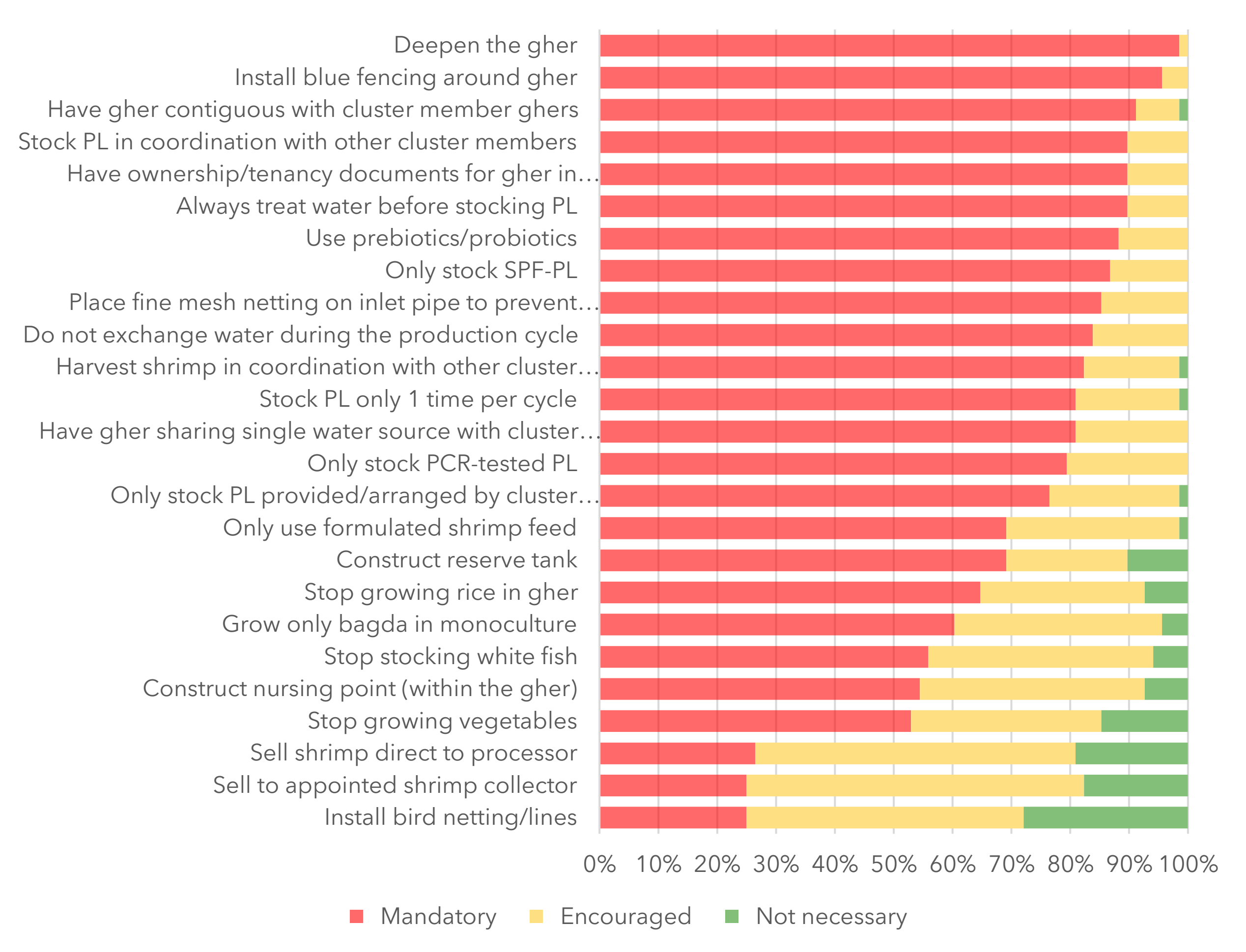
Table 2: Some features of clusters

Cluster organizer	DoF	BSFF	ACI	All
Number of clusters	**60**	**4**	**4**	**68**
Age of cluster (months)	23	9	16	21
Cluster is registered (=1)	93%	50%	100%	91%
Cluster has own bank account (=1)	100%	0%	25%	90%
Cluster has elected representatives (=1)	98%	100%	100%	99%
Cluster meets at least once a month (=1)	92%	25%	100%	88%
Number of meetings in the past 12 months	9	5	8	9
Days since most recent meeting (days)	108	116	244	117
Cluster has its own office (=1)	22%	0%	0%	19%
Pay membership fee to cluster	73%	0%	50%	68%
Number of ponds or ghers during 2023	25	20	25	25

Cluster organizer	DoF	BSFF	ACI	All
Number of clusters	**60**	**4**	**4**	**68**
Area (acres)	21	10	58	23
Average pond size in cluster (acres)	0.8	0.5	2.3	0.9
Has marketing contract with a processor	0%	0%	0%	0%
Has contract with input supplier	5%	25%	25%	7%
Interacted with shrimp clusters in other villages to trade experience	78%	100%	75%	79%
Percentage of clusters that received training in the past 24 mths	100%	100%	100%	100%
Number of training received in the past 24 months	6	3	4	6
Number of members at inception	25	20	25	25
Number of members during 2023	25	20	25	25
Percentage of women members	24	29	5	23
Members mostly belong to the same religion	87%	75%	100%	87%
Members mostly have the same ethnic background/clan/kinship ties	77%	100%	100%	79%
Members most have same educational background	5%	0%	0%	4%
Mostly own the land they farm shrimp	68%	50%	0%	63%
Members don't interact or work with other groups in the village	15%	25%	0%	15%
Members don't interact or work with others outside the village	32%	50%	0%	31%
Liaison with the government for subsidies/benefits	80%	0%	0%	71%
Facilitate procurement of SPFPL on behalf of members	75%	100%	100%	78%
Facilitate PCRtesting of PL on behalf of members	60%	75%	50%	60%
Facilitate testing of water quality, etc. for members	62%	100%	75%	65%
Facilitate marketing of shrimp produced by cluster members	42%	75%	0%	41%
Facilitate acquiring credit for cluster members	8%	0%	0%	7%
Facilitate acquiring insurance for cluster members	2%	0%	25%	3%
Facilitate technical advice and extension	67%	50%	25%	63%
Very or moderately successful in securing member cooperation and coordination	53%	100%	100%	59%
Somewhat or extremely difficult for most members to follow cluster rules	55%	50%	100%	57%
Value a marketing contract greatly or somewhat	75%	100%	100%	78%
Value an input contract greatly or somewhat	78%	50%	100%	78%

Source: Authors.
Note: DoF = Department of Fisheries. BSFF = Bangladesh Shrimp and Fish Foundation. ACI = ACI Agrolink Ltd.

Figure 3: Practices mandated or encouraged by cluster



Source: Authors.

6.2. Cluster and non-cluster farmers compared

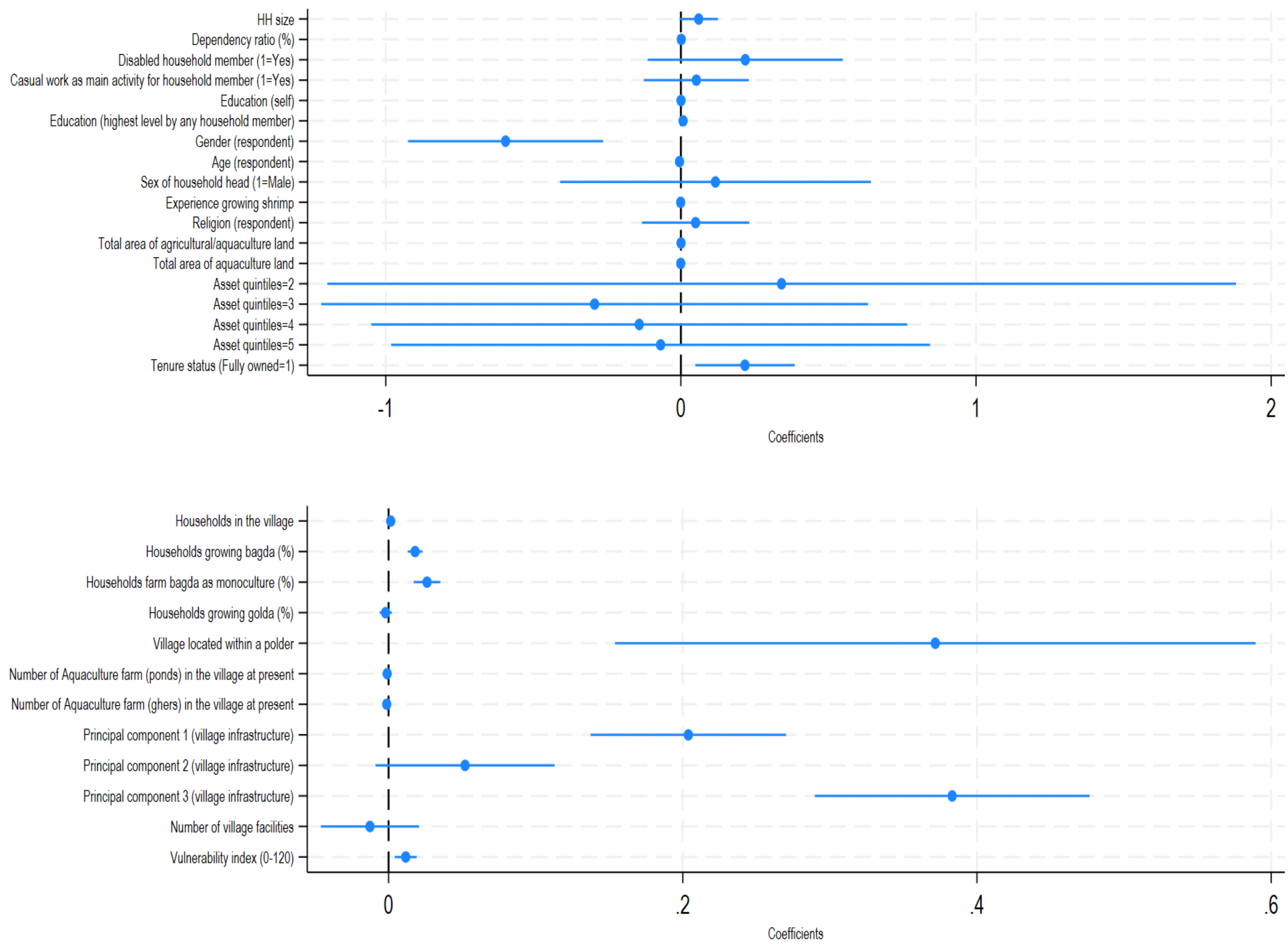
Our baseline data from the household survey suggests that the average age of farmer members in the cluster is 44 years old, with 20 years of shrimp farming experience, with an average pond size of 264 decimals (2.64 acres). 50% own the pond they have allocated to cluster production, 93% are male

We first look at the differences in individual and household characteristics between cluster and non-cluster farmers, depicted in Figure 4 as a plot of the coefficients from our probit model described earlier (Model 1). Most coefficients are statistically insignificant, suggesting that on average the two groups in our sample are like each other based on observable characteristics. The only major difference seems to be that more cluster farmers are likely to be female compared to non-cluster control farmers ($p < 0.05$), which is understandable given that there is some positive selection to ensure female farmer participation, especially in the DoF and BSFF interventions. These results suggest that our non-cluster farmers are a suitable comparison group for the cluster farmers.[7]

[7] Appendix Table 2 shows the mean differences in characteristics between cluster members and non-members, capturing outcomes and covariates of interest.

There are however significant differences in placement effects – i.e. clusters seem to have been organized in villages that systematically differ from other villages in our sample, which were adjacent to the sample villages. While this does not suggest that cluster organizers were selective in where these clusters were initiated but rather that in our sample, comparisons between cluster and non-cluster farmers must address explicitly that they may come from very different contexts, on average. Cluster villages tend to be larger, with more farmers growing bagda in monoculture, more likely to be located in a polder and endowed with better infrastructure (Figure 4).[8] We extract the first three principal components to proxy infrastructure, that includes access to roads, electricity, water, social infrastructure – like schools, health centers, etc.

Figure 4: Individual, household and village characteristics between cluster and control farmers



Notes: Authors' estimations. These are coefficients of a probit regression model described in Equation (1) that regresses whether a farmer belongs to a cluster on a vector of individual, household and village characteristics collected during the baseline survey. The individual/household characteristics and village characteristics have been plotted on separate subgraphs to accommodate the varying scales of the coefficients.

[8] See Appendix Table 1 for a description of how the variables are generated.

6.3. Test of common trends

As mentioned earlier, a key assumption of DID research designs is that the treatment and control groups share common trends in outcome variables in the period(s) leading up to the treatment. This assumption enables us to treat the change in the control group outcome before and after treatment as a change that the treatment group would have experienced in the absence of treatment. We test this assumption for our principal outcome net profit per acre of pond, by implementing the following regression, a DID, using data on our outcomes of interest for 2021 and 2022, both pertaining to seasons before the cluster intervention comments. Our data for these production cycles were collected as part of the Baseline Survey to be able to formally test the common trends assumption.

$$Y_{it} = \pi_0 + \pi_1 Year + \pi_2 Cluster + \pi_3 Cluster \times Year + \epsilon_v \quad (2)$$

Where Y_{it} is net profit per acre of pond, Year refers to 2022 (with 2021 as the base year) and Cluster refers to whether a farmer belongs to a cluster. The interaction term would identify the change in net profits for cluster farmers between 2022 and 2021 relative to non-cluster farmers. We include no controls in this set of models. The results of this model are presented in Appendix Table 3, but we note here that for the ultimate outcome of interest, the common trends assumption holds.

7. Results

In this section, we discuss the results of our analysis in two parts. We first focus on the first order outcomes, i.e., pond management practices, before moving on to the key outcome net profit per acre of pond and the adjustments and tradeoffs.

7.1. Impacts on pond management practices

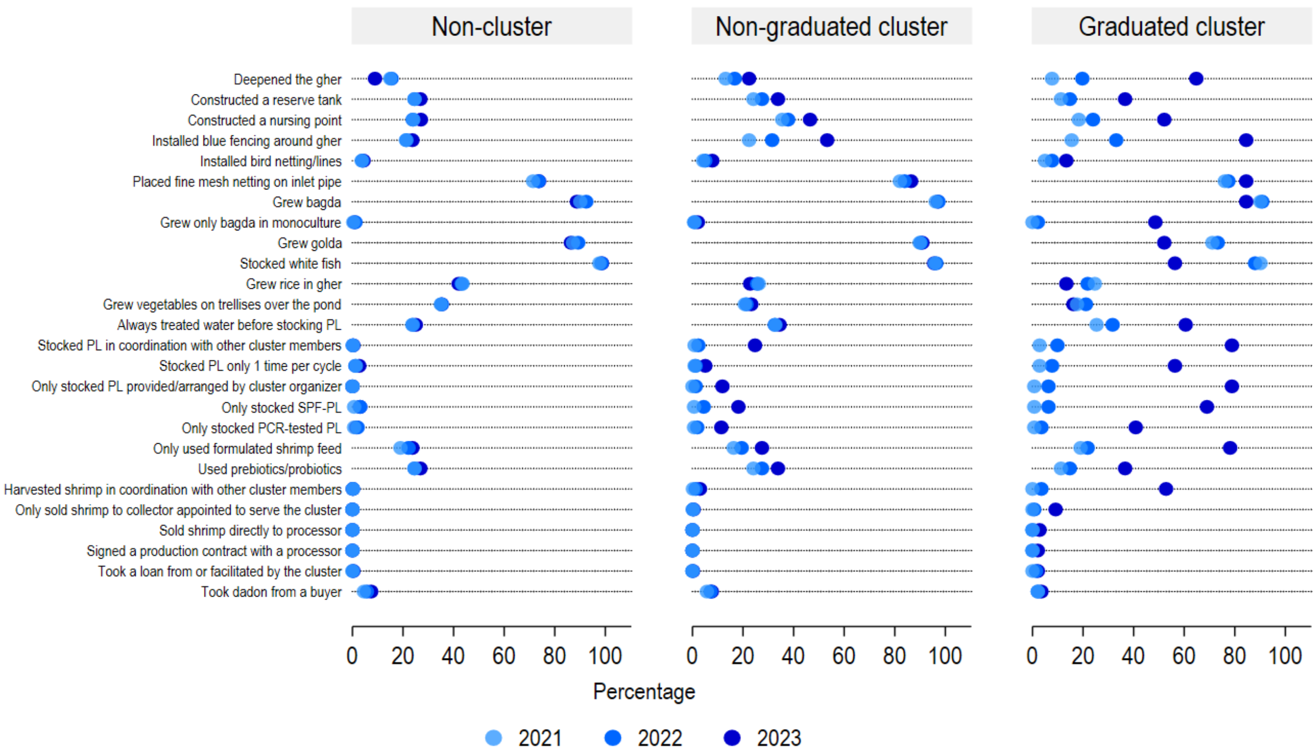
Figure 5 shows the extent to which different groups of farmers adopted these and when. These foreshadow our results on the impact of the cluster intervention on pond management practices. There is a clear uptick in some of the prescribed practices among cluster farmers, more prominent among those belonging to graduated clusters.

Our DID estimates reveal that there are significant gains in the uptake of pond management "best" practices on the part of cluster farmers (both graduated and all) relative to non-cluster farmers (Table 3). These practices include the use of improved seed (SPF-PL), pond deepening, biosecurity measures (fencing, bird netting, control of water inlets), growing bagda shrimp in monoculture, improved formulated feed use, prebiotic and probiotic use, and water treatment measures, among others.

The level of uptake of these improved farming methods among cluster farmers is high relative to control farmers, irrespective of a farmer being part of a "graduated" cluster – even if a cluster did not receive a matching grant to subsidize the associated costs, farmers within the cluster were still more likely to adopt improved practices. This is an encouraging result for the cluster interventions, suggesting that the training content and pond management practices themselves are acceptable to farmers.

To investigate possible spillover effects, we look at the same outcomes comparing our spillover sample (non-cluster farmers in the same village as cluster farmers) to non-cluster farmers in neighboring villages. We do not observe any significant impacts on the uptake of improved practices for this group, suggesting that training and practices were not transferred to (or adopted by) non-cluster farmers. In field visits, we did see evidence of such learning, which practice specifically but apparently not on a scale that would reflect in the sample.

Figure 5: Uptake of pond management practices among cluster and non-cluster farmers



Source: Authors based on Baseline and Endline Surveys.

Table 3: Impacts on the uptake of pond management "best" practices

Model >	Any cluster member	Graduated cluster member	Nongraduated cluster member	Spillover effects
	N = 2420	N = 1474	N = 2136	N = 1190
Pond management practices				
Share of specific pathogen free (SPF)PL in total PL stocked (%)	23.3***	55.9***	12.2***	0.8
	(3.9)	(9.4)	(3.1)	(1.6)
Deepened the gher (Yes=1)	0.215***	0.538***	0.117***	0.017
	(0.042)	(0.087)	(0.037)	(0.031)
Constructed a reserve tank (Yes=1)	0.084**	0.208**	0.044	0.052
	(0.036)	(0.059)	(0.041)	(0.039)
Constructed a nursing point (Yes=1)	0.104***	0.253***	0.061**	0.009
	(0.025)	(0.051)	(0.024)	(0.024)
Installed blue fencing around gher (Yes=1)	0.247***	0.506***	0.180***	0.027
	(0.041)	(0.067)	(0.041)	(0.033)
Installed bird netting/lines (Yes=1)	0.035**	0.056**	0.028**	0.004
	(0.014)	(0.038)	(0.013)	(0.011)

Model >	Any cluster member	Graduated cluster member	Nongraduated cluster member	Spillover effects
	N = 2420	N = 1474	N = 2136	N = 1190
Pond management practices				
Placed fine mesh netting on inlet pipe to prevent wild PL/fish fry from entering (Yes=1)	0.027	0.061	0.017	0.020
	(0.018)	(0.037)	(0.019)	(0.014)
Only stocked SPFPL (Yes=1)	0.252***	0.593***	0.130***	0.001
	(0.050)	(0.091)	(0.046)	(0.011)
Only used formulated shrimp feed (Yes=1)	0.186***	0.566***	0.080***	0.013
	(0.034)	(0.062)	(0.020)	(0.014)
Used prebiotics/probiotics (Yes=1)	0.084**	0.208**	0.044	0.052
	(0.036)	(0.059)	(0.041)	(0.039)
Grew bagda (Yes=1)	0.022	0.044	0.036**	0.024
	(0.020)	(0.056)	(0.017)	(0.028)
Grew only bagda in monoculture (Yes=1)	0.124***	0.474***	0.014**	0.001
	(0.031)	(0.083)	(0.007)	(0.008)
Grew golda (Yes=1)	0.019	0.220	0.046**	0.010
	(0.030)	(0.086)	(0.021)	(0.014)
Always treated water before stocking PL (Yes=1)	0.103***	0.347***	0.032	0.010
	(0.039)	(0.073)	(0.039)	(0.012)
Stocked white fish (Yes=1)	0.084***	0.320***	0.010	0.010
	(0.022)	(0.065)	(0.008)	(0.008)
Stocked PL only 1 time per cycle (Yes=1)	0.128***	0.471***	0.024*	0.015
	(0.030)	(0.073)	(0.013)	(0.011)
Only stocked PL provided/arranged by cluster organizer (Yes=1)	0.246***	0.730***	0.095**	0.000
	(0.046)	(0.066)	(0.039)	(0.000)
Only stocked PCR-tested PL (Yes=1)	0.160***	0.366***	0.094**	0.009
	(0.037)	(0.064)	(0.037)	(0.012)
Stocked PL in coordination with other cluster members (Yes=1)	0.323***	0.702***	0.210***	0.003
	(0.056)	(0.070)	(0.064)	(0.004)
Harvested shrimp in coordination with other cluster members (Yes=1)	0.126***	0.504***	0.016*	0.001
	(0.030)	(0.067)	(0.009)	(0.001)

Source: Authors' estimations.

*Notes: (1) *** p<0.01, ** p<0.05, * p<0.1. (2) All models include upazila (subdistrict) fixed effects. (3) Errors are clustered at the level of the clusters represented by the intervention (i.e., the contiguous ponds/villages associated with the cluster). (4) Column 1 compares cluster members pooled across models with pooled comparison. Column 2 compares graduated cluster members (pooled) across the same pooled comparison in Column 1. Column 3 drops all cluster members and compares non-cluster farmers in the same villages as the cluster with those famers in neighboring villages. (5) The N in the column heading represents the total number of observations in the regression.*

7.2. Impacts on net profit and the costs of adjustments

We now turn to the results from our DID estimates for our ultimate outcome—net profits, and secondary outcomes, namely impacts on food security, dietary diversity, shrimp species diversification, and income from fish sales. We present two models, one without village controls (Table 4) and our preferred model with village controls (Table 5). Recall that we found significant differences between the likelihood of farmers belonging to a cluster based on village characteristics. To the extent that some of these drive both cluster membership and net profits, we need to control for these. The village characteristics we include are of two kinds: time invariant and time variant (climate and weather shocks during the production year, village facilities).

Unlike the uptake of practices, we do not find any significant differences in profits between cluster and control farmers. While cluster farmers overall are more likely to record higher profits than non-cluster farmers (BDT 20859.5), the distributions overlap and the difference does not appear to be significant. Graduated cluster farmers too appear to record a higher net profit (BDT 11069.6 per acre) compared to non-cluster farmers, but again, this difference does not seem to be significant. We find that nongraduated cluster farmers, i.e. farmers in clusters that do not go all the way and do not benefit from subsidies, appear to gain marginally in net profits adopting key practices, even while facing lower reduction in costs, although this is not robust to the inclusion of village controls.

In terms of secondary outcomes, cluster farmers' income from fish sales were negatively affected compared to non-cluster farmers. For graduated cluster farmers, this was large and significant, losing out on income from fish sales that averaged around BDT 31322.5 per acre compared to control farmers. This is unsurprising as the graduated cohort is the one most likely to have continued monoculture bagda shrimp production, as is mandated by the cluster farming rules. Cluster farmers are also significantly more likely to have farmed fewer species of shrimp, reflected in significantly higher Herfindahl-Hirshman Index scores compared to non-cluster farmers. Curiously, cluster farmers appear to have poorer food security outcomes relative to non-cluster farmers as well. The most likely explanation for this is the lower or absence of production of fish and vegetables.

We finally look at variables that may act as pathway mechanisms for our primary and secondary outcomes—productivity, mortality rates, production costs, and incomes from shrimp sales (Table 5).

Production costs (of farming shrimp and/or fish) were significantly lower for both cluster farmers as a whole (by BDT 12938.5 per acre) and more pronouncedly for graduated farmers (BDT 36616.4 per acre) compared to non-cluster farmers. Cluster farmers—and graduated farmers in particular—were more likely to have received subsidized inputs, which would drive down production costs.

Despite promoting the use of supposedly disease-free seed in the form of SPF-PL through these cluster interventions, mortality rates were not significantly different between cluster and non-cluster farmers. Curiously, graduated cluster farmers, who are most likely to have used SPF-PL had somewhat higher mortality rates compared to non-cluster farmers, although this difference is not statistically significant.

Importantly, bagda shrimp productivity measured as kilogram yield per acre of pond is not significantly different between cluster and non-cluster farmers; in fact, graduated cluster farmers appear to have slightly lower yields compared to control farmers. This could be the result of late starts to the production cycle for cluster farmers due to delays in the disbursement of subsidized inputs, or lower than expected survival performance of the disease-free PL. Indeed, graduated cluster farmers experienced somewhat lower total productivity of fish and shrimp (94.9 kg per acre lower) compared to non-cluster farmers, although these differences are not statistically significant.

These mixed results culminate in modest but insignificant improvements in incomes from selling bagda shrimp for cluster farmers when compared to non-cluster control farmers. As seen earlier, graduated farmers lost out on incomes from selling fish, meaning that their total income from selling fish and shrimp was lower (by BDT 14830.1 per acre) compared to non-cluster farmers.

7.3. Which practices are associated with improvements in net profits?

Given that the cluster program is a bundled intervention and promotes a set of pond management practices, it is possible that the various practices do not all contribute to improvements in net profit. Further, given the variation in uptake of practices even amongst cluster farmers, it would be useful to understand the correlation between the adoption of a specific practice and net income per acre of pond.

Figure 6 presents the coefficients of a regression of net incomes per acre of pond on the pond management practices, treating the cluster not as a binary variable but as a set of component practices. In this model, we run a simple panel regression rather than a DID to uncover the efficacy of specific pond management practices. Each coefficient represents the association with net incomes per acre of pond, given other practices. First, only a few practices seem to be statistically significantly associated with net incomes. Second, not all the practices associated with cluster intervention have positive associations. Strikingly, it seemed that the stocking of the SPF-PL provided by the cluster organizer, exclusively, seemed to have a large negative association with net incomes.

Table 4: Impacts on net profits and the costs of adjustments (without village controls)

Outcomes	Any cluster member	Graduated cluster member	Non-graduated cluster member	Spillover effects
	N = 2420	N = 1474	N = 2136	N = 1190
Ultimate outcome				
Net profit (BDT/acre)	20859.5	11069.6	23435.8	23047.3
	(22767.6)	(37189.3)	(22477.0)	(34082.0)
Pathway outcomes and adjustments				
Cost of production (BDT/acre)	-14954.9***	-40167.1***	-7504.2*	1563.6
	(4389.8)	(7444.7)	(4067.4)	(5567.7)
Total revenue (BDT/acre)	5904.6	-29097.5	15931.6	24610.9
	(22594.4)	(38138.4)	(21874.5)	(32652.0)
Revenue from shrimp sales (BDT/acre)	11000.2	13951.3	9874.4	14664.2
	(18833.8)	(31222.2)	(17913.1)	(30638.9)
Revenue from fish sales (BDT/acre)	-3010.3	-31322.5***	5278.0	-1014.1
	(5991.7)	(10994.1)	(5983.9)	(8767.5)
Revenue from vegetable sales (BDT/acre)	-2486.9	-12144.5**	338.1	10156.1
	(7817.8)	(5590.1)	(9340.2)	(10968.1)
Pathway indicators				
Productivity of fish & shrimp (kgs/acre)	14.2	-149.2	62.9	57.7
	(70.3)	(100.1)	(67.6)	(113.7)

Outcomes	Any cluster member	Graduated cluster member	Non-graduated cluster member	Spillover effects
	N = 2420	N = 1474	N = 2136	N = 1190
Productivity of all shrimp (kgs/acre)	39.5	23.8	44.0	72.1
	(57.0)	(63.5)	(57.1)	(96.9)
Productivity of bagda (kgs/acre)	0.5	-13.2	5.1	-10.6
	(10.4)	(31.6)	(8.8)	(10.1)
Productivity of golda (kgs/acre)	39.6	49.1	36.0	89.2
	(51.2)	(56.2)	(50.2)	(95.8)
Mortality rate (%)	1.2	10.3	-1.7	-0.0
	(2.4)	(7.3)	(2.7)	(2.4)
Herfindahl-Hirschman Index (shrimp)	0.112***	0.405***	0.025***	-0.001
	(0.022)	(0.046)	(0.008)	(0.007)
Secondary outcomes				
Household Food Insecurity and Access Score (HFIAS)	0.478**	0.509	0.467**	0.742**
	(0.195)	(0.380)	(0.216)	(0.327)
Household Dietary Diversity Score (HDDS)	-0.107	-0.042	-0.124	-0.349*
	(0.132)	(0.234)	(0.146)	(0.203)

*Notes: (1) *** p<0.01, ** p<0.05, * p<0.1. (2) All models include upazila (subdistrict) fixed effects. (3) Errors are clustered at the level of the clusters represented by the intervention (i.e., the contiguous ponds/villages associated with the cluster). (4) Column 1 compares cluster members pooled across models with pooled comparison. Column 2 compares graduated cluster members (pooled) across the same pooled comparison in Column 1. Column 3 drops all cluster members and compares non-cluster farmers in the same villages as the cluster with those farmers in neighboring villages.*

Table 5: Impacts on net profits and the costs of adjustments (with village controls)

Outcomes	Any cluster member	Graduated cluster member	Non-graduated cluster member	Spillover effects
	N = 2420	N = 1474	N = 2136	N = 1190
Ultimate outcome				
Net profit (BDT/acre)	24292.8	21786.3	27455.3	22220.0
	(18304.2)	(31127.6)	(18364.1)	(33204.9)
Pathway outcomes and adjustment				
Cost of production (BDT/acre)	-12938.5***	-36616.4***	-4630.6	1990.5
	(4668.9)	(7977.1)	(4619.1)	(5604.0)
Total revenue (BDT/acre)	11354.3	-14830.1	22824.6	24210.5
	(18210.1)	(32651.0)	(19144.7)	(31744.2)
Revenue from shrimp sales (BDT/acre)	13819.1	22143.9	11512.2	14106.4
	(14369.6)	(25940.8)	(14044.5)	(29884.4)
Revenue from fish sales (BDT/acre)	-3151.6	-24057.5*	4193.7	-736.4
	(6142.8)	(13316.9)	(5930.5)	(8735.4)

Outcomes	Any cluster member	Graduated cluster member	Non-graduated cluster member	Spillover effects
	N = 2420	N = 1474	N = 2136	N = 1190
Revenue from vegetable sales (BDT/acre)	132.4	-13234.2	6232.3	10000.8
	(8721.2)	(9015.2)	(10316.3)	(10835.4)
Pathway indicators				
Productivity of fish & shrimp (kgs/acre)	22.5	-94.9	62.1	56.9
	(53.4)	(94.2)	(50.9)	(111.5)
Productivity of all shrimp (kgs/acre)	47.7	51.3	46.7	70.0
	(40.1)	(52.3)	(37.7)	(94.6)
Productivity of bagda (kgs/acre)	2.0	-12.2	4.4	-10.9
	(10.0)	(30.4)	(8.0)	(10.2)
Productivity of golda (kgs/acre)	47.2	76.2	40.5	87.5
	(38.7)	(50.8)	(35.7)	(93.4)
Mortality rate (%)	0.9	9.4	-2.3	0.0
	(2.5)	(6.2)	(2.6)	(2.4)
Herfindahl-Hirschman Index (shrimp)	0.117***	0.407***	0.025***	-0.002
	(0.022)	(0.052)	(0.007)	(0.007)
Secondary outcomes				
Household Food Insecurity and Access Score (HFIAS)	0.560***	0.835**	0.522**	0.733**
	(0.186)	(0.339)	(0.220)	(0.329)
Household Dietary Diversity Score (HDDS)	-0.113	-0.069	-0.138	-0.348*
	(0.132)	(0.233)	(0.146)	(0.206)

Source: Authors' estimations.

*Notes: (1) *** p<0.01, ** p<0.05, * p<0.1. (2) All models include upazila (subdistrict) fixed effects. (3) Errors are clustered at the level of the clusters represented by the intervention (i.e., the contiguous ponds/villages associated with the cluster). (4) Column 1 compares cluster members pooled across models with pooled comparison. Column 2 compares graduated cluster members (pooled) across the same pooled comparison in Column 1. Column 3 drops all cluster members and compares non-cluster farmers in the same villages as the cluster with those famers in neighboring villages.*

Figure 6: Cluster components and their correlation with outcomes

Source: Author's calculations. The full regression results are available from the authors

8. Concluding remarks

In this study, we evaluated the impact of clustering shrimp farming on a range of outcomes for participating farmers including pond management practices, costs, incomes and profitability from cluster farming, including any costs of adjustments or tradeoffs that the farmer may face in meeting the demands /mandates of being part of a cluster. We further explored spillover effects of clusters, investigating whether farmers who are not part of clusters but are located in the same village as the clusters adopt practices that cluster farmers adopt.

We find that clusters lead to significant impacts on adoption of more scientific pond management practices and cluster farmers seem to have adhered to several requirements laid down as prerequisites for cluster membership. Expectedly, these effects are stronger for those in graduated clusters relative to those in nongraduated clusters – affirming that the incentive of matched grants did prompt a few clusters to adhere to DoF's set of recommendations. We find little to no evidence of adoption by non-cluster farmers, by way of spillover and our qualitative evidence suggests that such spillovers do happen but perhaps not on a scale that is detected by quantitative analysis.

Our key finding, however, is that cluster farming of shrimp has no statistically significant short-term impacts on net profits, although they remain reassuringly positive. It appears that the reduction in costs, on account of subsidies, that are significant, is overturned by reductions in incomes from vegetables and fish. We caveat this finding noting that our Endline came just one complete cycle of cluster shrimp farming. Thus far, the intervention has focused on production practices without a strong market linkage component and cluster farmers still use traditional marketing channels and receive similar prices as non-cluster farmers.

A key insight from our analysis is that the graduated farmers fare somewhat worse than the nongraduated clusters, despite benefitting from subsidies that substantially lower costs. Graduated cluster farmers appear, having adhered more closely to the production practices prescribed, including a switch to monoculture of bagda and abandoning vegetable and rice production. They, however, seem to have paid a penalty for doing so. This shift is reflected in higher food insecurity. Interestingly, it appears that the local reduction in vegetable/rice cultivation affects the larger community within the village, with non-cluster farmers in cluster villages too reporting higher food insecurity.

Our study affirms some of the findings of other studies – that clustering promotes adoption of specific practices but suggests that although there exists potential for a growth in net incomes, there are potentially serious tradeoffs. Perhaps, there is scope for a middle ground of cluster farming that is not too prescriptive and does not push farmers to an intensive monoculture of shrimp. Doing so likely involves costs of adjustments that are unsustainable (without subsidies), entail losses from income foregone from abandoning vegetable and fish farming, vulnerabilities that come from monoculture and may undermine food security, not just of the cluster farmers but of the community at large.

References

Abdelaziz, F., N. Abdelghany, M. Ellis, A. William, and X. Zhang. 2021. "Cluster-Based Development in Egypt: A Study of External Shocks to the Leather and Medicinal and Aromatic Plant Sectors." *Middle East and North Africa Regional Research Program. Working Paper* 37.

Barham, J., and C. Chitemi. 2009. "Collective Action Initiatives to Improve Marketing Performance: Lessons from Farmer Groups in Tanzania." *Food Policy* 34 (1): 53–59. https://doi.org/10.1016/j.foodpol.2008.10.002.

Belton, Ben; Breisinger, Clemens; Kassim, Yumna; Pal, Barun Deb; Narayanan, Sudha; and Zhang, Xiaobo. 2024. Cluster-based development: Lessons from country experiences for Odisha, India. South Asia Policy Perspectives 1. New Delhi, India: International Food Policy Research Institute. https://hdl.handle.net/10568/152082.

Belton, Ben, and Hazrat Ali. 2022. "Farm Survey Results." In *Presentation at the Harnessing Machine Learning Project Outreach Workshop with Development Partners*. Dhaka.

Belton, Ben, Manjurul Karim, Shakuntala Thilsted, Khondker Murshed-E-Jahan, William Collis, and Michael Phillips. 2011. "Review of Aquaculture and Fish Consumption in Bangladesh." http://hdl.handle.net/1834/24444.

Bhattacharya, P. 2010. "A Comparative Study of Traditional and Scientific Shrimp Farming in West Bengal: A Technical Efficiency Analysis." *The Indian Economic Journal* 58 (2): 81–100. https://doi.org/10.1177/0019466220100206.

Dureti, G.G., and M.P. Tabe-Ojong Jr. 2024. "Land as a Binding Constraint to Cluster-Based Development in Ethiopia: To Cluster or Not to Cluster?" *PLOS ONE* 19 (4): 0298784. https://doi.org/10.1371/journal.pone.0298784.

Dureti, Guyo Godana, Martin Paul Jr. Tabe-Ojong, and Enoch Owusu-Sekyere. 2023. "The New Normal? Cluster Farming and Smallholder Commercialization in Ethiopia." *Agricultural Economics* 54 (6): 900–920. https://doi.org/10.1111/agec.12790.

Endalew, B., A. Elias, and K. Yasunobu. 2024. "Impact of Cluster Farming on Smallholder Farmers Teff Commercialization in Ethiopia." *CABI Agriculture and Bioscience* 5 (1): 18. https://doi.org/10.1186/s43170-024-00220-7.

Fischer, E., and M. Qaim. 2012. "Linking Smallholders to Markets: Determinants and Impacts of Farmer Collective Action in Kenya." *World Development* 40 (6): 1255–68. https://doi.org/10.1016/j.worlddev.2011.11.018.

Food and Agriculture Organization of the United Nations. 2010. "Agro-Based Clusters in Developing Countries: Staying Competitive in a Globalized Economy." Food and Agriculture Organization of the United Nations. https://www.fao.org/4/i1560e/i1560e.pdf.

Goni, A.A., Y.U. Oladimeji, J.R. Mani, and A.S. Isah. 2023. "Do Cluster Farming Practices Improve Profitability and Productivity Indices of Smallholder Rice Farmers? Evidence from Borno State, Nigeria." *Agricultural Socio-Economics Journal* 23 (2): 221–30. https://doi.org/10.21776/ub.agrise.2023.023.2.11.

Hassan, S., R. Kasin, and O. Oluwatoyin. 2017. "Factors Influencing Cocoa Farmers Smallholder Clusters in Adoption of Technology: A Review Paper." https://www.semanticscholar.org/paper/Factors-Influencing-Cocoa-Farmers-Smallholder-in-of-Hassan-Kasin/db29cbaa92ae18e909e922aaaeb8d9f33139fdd0.

Joffre, O.M., P.M. Poortvliet, and L. Klerkx. 2019. "To Cluster or Not to Cluster Farmers? Influences on Network Interactions, Risk Perceptions, and Adoption of Aquaculture Practices." *Agricultural Systems* 173:151–60. https://doi.org/10.1016/j.agsy.2019.02.011.

Jr Tabe-Ojong, Martin Paul, and Guyo Godana Dureti. 2023. "Are Agro-Clusters Pro-Poor? Evidence from Ethiopia." *Journal of Agricultural Economics* 74 (1): 100–115. https://doi.org/10.1111/1477-

9552.12497.

Kabir, R.I., M.N. Bin Khaled, S. Narayanan, and S. Rashid. 2023a. "Shocks and the Determinants of Resilience: Fish and Shrimp Value Chains in Bangladesh after Covid-19." *Applied Economic Perspectives and Policy* 45 (4): 1835–62.

Kabir, Razin Iqbal, Sudha Narayanan, Ben Belton, Ricardo Hernandez, and Mohammad Mahfujul Haque. 2023b. "Shrimp Value Chains in Bangladesh: A Scoping Study of Possible Research Interventions." *Rethinking Food Markets Initiative Note 8*. https://doi.org/10.2499/p15738coll2.136869.

Kariuki, G. 2005. "Initiatives for Rural Development Through Collective Action: The Case of Household Participation in Group Activities in The Highlands of Central Kenya." https://www.semanticscholar.org/paper/INITIATIVES-FOR-RURAL-DEVELOPMENT-THROUGH-ACTION-%3A-Kariuki/829643681ed51967b487ead3a6defdb9457008f2.

Kurokawa, K. 2009. "Effectiveness and Limitations of the 'One Village One Product' (OVOP) Approach as a Government-Led Development Policy: Evidence from the Thai 'One Tambon One Product' (OTOP." *Studies in Regional Science* 39 (4): 977–89.

Montiflor, M.O., P.J. Batt, and R. Murray-Prior. 2008. "Cluster Farms in Mindanao: Are Smallholder Farmers." *Expectations Being Fulfilled?* 8 (2).

Montiflor, M.O., P.J. Batt, and R. Murray-Prior. 2009. "Socio-Economic Impact of Cluster Farming for Smallholder Farmers in Southern Philippines." *Acta Horticulturae*, no. 809 (January), 193–200. https://doi.org/10.17660/ActaHortic.2009.809.19.

Murray-Prior, R.B., S.B. Concepcion, P.J. Batt, F. Israel, D.I. Apara, R.H. Bacus, M.F. Rola-Rubzen, et al. 2012. "Experiences with the Catholic Relief Services' Clustering Process for Agroenterprise Development and Some Suggestions for Improvements." In *Smallholder HOPES: Proceedings of the ACIAR-PCAARRD Southern Philippines Fruits and Vegetables Program Meeting*, 181–89. http://hdl.handle.net/20.500.11937/25828.

Oakeshott, J. 2016. "Sustainable Smallholder Farming Clusters in the Philippines." *Acta Horticulturae* 1128:339–46. https://doi.org/10.17660/ActaHortic.2016.1128.52.

Rola-Rubzen, M.F., R. Murray-Prior, P.J. Batt, S.B. Concepcion, R.R. Real, R.J.G. Lamban, J.T. Axalan, et al. 2013. "Impacts of Clustering of Vegetable Farmers in the Philippines." In *Smallholder HOPES – Horticulture, People and Soil: Proceedings of ACIAR-PCAARRD Southern Philippines Fruits and Vegetables Program Meeting*, 190–202. http://hdl.handle.net/20.500.11937/28369.

Thriveni, K., R. Jayaraman, V. Senthikumar, N.V. Sujathkumar, C. Anand, and T.V. Ramana. 2022. "Technical Efficiency Analysis of Shrimp Farms in Andhra Pradesh, India Using Stochastic Frontier Approach: Technical Efficiency Analysis of Shrimp Farms Using Stochastic Frontier Approach." *Indian Journal of Fisheries* 69 (2). https://doi.org/10.21077/ijf.2022.69.2.113857-14.

Umesh, N.R., A.B.C. Mohan, G. Ravibabu, P.A. Padiyar, M.J. Phillips, C.V. Mohan, and B.V. Bhat. 2010. "Shrimp Farmers in India: Empowering Small-Scale Farmers through a Cluster-Based Approach." In *Success Stories in Asian Aquaculture*, edited by S.S. Silva and F.B. Davy, 41–66. Springer Netherlands. https://doi.org/10.1007/978-90-481-3087-0_3.

van der Pijl, Willem. 2014. "An Update of Shrimp and Prawn Supply Chain Initiatives in Bangladesh: Recommendations for Inclusive Shrimp Supply Chain Development for the STDF Project." www.wageningenUR.nl/en/lei.

van der Pijl, Willem, and Arie Pieter van Duijn. 2012. "CBI Report: The Bangladeshi Seafood Sector - A Value Chain Analysis." www.cbi.eu.

Zhang, X. 2023. "Cluster-Based Agricultural Development: A Comparison between China and Africa." *International Food and Agribusiness Management Review* 26 (1).

Appendix

Appendix Table 1: List of variables and description

Variable label	Variable construction
Net profit (taka/acre)	Net profit per acre = total revenue per acre - total cost per acre
Cost (taka/acre)	Total cost per acre = (cost of deepening the pond + cost of constructing a reserve tank + cost of buying aerator)/5 + (cost of installing blue fencing + cost of installing bird netting)/2 + cost of constructing a nursing point + rent + cost of hired labor + cost of stocking PL + cost of feed + cost of transportation of feed + non-feed costs + cost of growing rice + cost of growing vegetables and fruits; all these costs are in per acre term.
Total revenue (taka/acre)	Total revenue per acre = revenue from fish and shrimp + revenue from rice + revenue from vegetables and fruits; all revenues are in per acre term
Revenue from shrimp (taka/acre)	Revenue from selling all types of shrimp; Revenue from each species was calculated by multiplying the average selling price by the quantity sold. In the baseline, the average price for that year was used, since seasonal data was not collected. However, in the endline, the average price for each season was used, and seasonal revenues were aggregated to calculate the yearly revenue. All quantities were from the sampled ponds.
Revenue from fish (taka/acre)	Revenue from selling all types of fish; Similar calculation method as shrimp revenue.
Revenue from vegetables and fruits (taka/acre)	Revenue from selling all types of vegetables and fruits; Revenue of vegetables and fruits from the production year were directly collected from the farmers.
Herfindahl-Hirschman Index	The formula: $Total\ production, E_T = \sum_{i=1}^{n} E_i;\ E_i$ = production of each species $Fraction\ of\ each\ species, w_i = {}^{E_i}/_{E_T}$ $The\ HHI\ index, HHI = \sum_i^n w_i^2$
HFIAS Score	Following the standard manual; https://www.fantaproject.org/sites/default/files/resources/HFIAS_ENG_v3_Aug07.pdf
HDDS Score	Following the standard manual; https://www.fantaproject.org/sites/default/files/resources/HDDS_v2_Sep06_0.pdf
Productivity of fish and shrimp	Production of fish and shrimp in per acre sampled pond area
Productivity of shrimp	Production of shrimp in per acre sampled pond area
Productivity of bagda	Production of bagda in per acre sampled pond area
Productivity of golda	Production of golda in per acre sampled pond area
Mortality rate (%)	The mortality rate was calculated by first determining the average mortality rate for each disease and then calculating the overall average of these disease-specific average mortality rates.

Variable label	Variable construction
Dependency ratio (%)	Dependency ratio = (number of household members aged below 18 / household size) * 100
Experience growing shrimp	Experience of the household in growing shrimp till 2024
Asset quintiles	The sample size is divided into quintiles based on wealth index which is calculated using the EquityTool.
Number of village facilities	This index was calculated by adding the number of facilities available to a village. The specific facilities are fish hatchery, fish nursery, fish seed trader, shrimp seed trader, patilwallah, fish feed supplier, vetrinary medicine shop, agricultural input shop, fish trader, shrimp trader, fish retailer, fish harvesting team, earth cutting team, ice factory, mechanical repair shop, agricultural machinery shop, mechanical excavators for hire, Depot, Arat, and shimp collection center operated by a processor. If a facility is available to a village, that variable takes a value of 1. As the number of facilities considered is 20, the value of this index varies between 0 to 20.
Vulnerability index (0-120)	This index, available only for the baseline, is calculated by summing the occurrence of an event multiplied by the number of times it happened in the past decade for 12 distinct events.The events under cosideration are floods, droughts, extreme high temperatures, extreme low temperatures, rapid changes in temperature, long period with dense cloud cover, intense rainfall events, high wind stroms, storm surges, saline intrusion, irregular rainfall, and waterlogging.

Source: Authors.

Appendix Table 2: Summary statistics of key variables of interest

	Non-cluster farms (595)	Cluster farms (615)	Total (1,210)	Test
Outcomes of interest				
Net profit (taka/acre)	100,214	84,269	92,110	
Cost (taka/acre)	144,647	145,663	145,164	
Total revenue (taka/acre)	244,861	229,932	237,273	
Revenue from shrimp (taka/acre)	147,767	159,696	153,830	
Revenue from fish (taka/acre)	75,042	57,218	65,983	***
Revenue from vegetables (taka/acre)	13,147	8,111	10,588	***
Herfindahl-Hirschman Index	0.060	0.068	0.064	***
HFIAS Score	3	2	2	***
HDDS Score	9	9	9	
Productivity of fish and shrimp	737	610	672	**
Productivity of shrimp	267	256	262	
Productivity of bagda	98	134	116	***
Productivity of golda	125	84	104	
Mortality rate (%)	24	27	26	**
Share of SPF-PL in total PL stocked (%)	4	9	6	***
Deepened the gher (Yes=1)	15%	17%	16%	
Constructed a reserve tank (Yes=1)	25%	25%	25%	
Consturcted a nursing point (Yes=1)	24%	35%	29%	***
Installed blue fencing aorund gher (Yes=1)	21%	32%	27%	***
Installed bird netting/lines (Yes=1)	4%	6%	5%	
Placed fine mesh netting on inlet pipe to prevent wil PL/fish fry from entering	74%	82%	78%	***
Only stocked SPF-PL (Yes=1)	3%	5%	4%	*
Only used formulated shrimp feed (Yes=1)	22%	20%	21%	
Used prebiotics/probiotics (Yes=1)	25%	25%	25%	
Grew bagda (Yes=1)	92%	96%	94%	**
Grew only bagda in monoculture (Yes=1)	1%	1%	1%	
Grew golda (Yes=1)	89%	86%	88%	
Always treated water before stocking PL (Yes=1)	24%	32%	28%	***
Stocked white fish (Yes=1)	98%	94%	96%	***
Stocked PL only 1 time per cycle (Yes=1)	1%	3%	2%	**
Only stocked PL provided/arranged by cluster organizer (Yes=1)	0%	2%	1%	***
Only stocked PCR-tested PL (Yes=1)	2%	2%	2%	
Stocked PL in coordination with other cluster members (Yes=1)	0%	4%	2%	***

	Non-cluster farms (595)	Cluster farms (615)	Total (1,210)	Test
Harvested shrimp in coordination with other cluster members (Yes=1)	0%	2%	1%	***
Covariates				
Pond surface area (decimals)	89	84	86	
Distance to nearest water source (meters)	78	96	87	**
HH size	5	5	5	
Dependency ratio (%)	122	129	125	
Age (respondent)	45	44	44	
Experience growing shrimp	20	20	20	
Total area of agricultural/aquaculture land	252	316	285	***
Total area of aquaculture land	234	293	264	***
Tenure status (Fully owned=1)	47%	53%	50%	*
Tenure status (Fully or partially owned=1)	60%	64%	62%	
Pond has aerator (=1)	0%	1%	0%	*
Pond was flooded during production (=1)	33%	33%	33%	
Disabled household member (1=Yes)	6%	6%	6%	
Casual work as main activity for household members (1=Yes)	34%	33%	33%	
Education (self)				
Class 1	2%	3%	2%	
Class 2	4%	3%	4%	
Class 3	5%	3%	4%	
Class 4	7%	4%	5%	
Class 5	12%	11%	11%	
Class 6	3%	3%	3%	
Class 7	5%	5%	5%	
Class 8	13%	13%	13%	
Class 9	12%	14%	13%	
Secondary School	13%	12%	13%	
Higher Secondary	9%	10%	10%	
BA/BSC/Fazil	3%	6%	4%	
MA/MSC and above/Kamil	3%	4%	3%	
Preschool class (general)	0%	0%	0%	
Preschool (mosque-based)	0%	0%	0%	
Never attended school	9%	10%	9%	
Education (highest level by any household member)				
Class 1	0%	0%	0%	

	Non-cluster farms (595)	Cluster farms (615)	Total (1,210)	Test
Class 2	0%	0%	0%	
Class 3	0%	1%	0%	
Class 4	0%	0%	0%	
Class 5	3%	2%	3%	
Class 6	2%	1%	1%	
Class 7	4%	3%	4%	
Class 8	9%	7%	8%	
Class 9	12%	13%	13%	
Secondary School	23%	19%	21%	
Higher Secondary	25%	26%	25%	
BA/BSC/Fazil	10%	12%	11%	
MA/MSC and above/Kamil	10%	13%	11%	
Preschool class (general)	0%	0%	0%	
Preschool (mosque-based)	0%	0%	0%	
Never attended school	1%	1%	1%	
Gender (respondent)				
Female	4%	10%	7%	***
Male	96%	90%	93%	
Sex of household head				
Female	2%	3%	3%	
Male	98%	97%	97%	
Religion (respondent)				
Hindu	45%	48%	47%	
Muslim	55%	52%	53%	
Asset quintiles				
1	1%	1%	1%	
2	0%	0%	0%	
3	14%	11%	12%	
4	43%	40%	41%	
5	42%	49%	46%	

*Notes: *** p<0.01, ** p<0.05, * p<0.1.*

Appendix Table 3: Test of common trends assumption

	Net profit (taka/acre)	Cost (taka/acre)	Total revenue (taka/acre)	Revenue from shrimp (taka/acre)	Revenue from fish (taka/acre)	Revenue from vegetables (taka/acre)	Productivity of fish and shrimp	Productivity of shrimp
Cluster member (=1)	-15721.7	1747.4	-13974.3	12305.2	-17391.6***	-4985.4	-125.2*	-11.39
	(16862.6)	(5354.3)	(18992.1)	(14422.6)	(5987.4)	(3384.0)	(62.90)	(51.12)
Year=2021	-71976.5***	-66168.0***	-138144.4***	-90480.3***	-36796.1***	-7076.1***	-356.9***	-162.6***
	(20473.2)	(3825.1)	(22026.5)	(19287.6)	(4387.2)	(1855.8)	(63.59)	(56.80)
Cluster member (=1) # Year=2021	14269.9	2264.3	16534.2	-236.5	13153.3**	1549.6	113.4*	34.97
	(14974.0)	(5711.4)	(18296.3)	(15401.0)	(5407.4)	(1952.7)	(61.97)	(52.43)
Constant	100100.3***	144275.4***	244375.7***	147575.7***	74822.2***	13121.6***	735.9***	267.4***
	(20053.0)	(4309.3)	(21305.8)	(18703.3)	(4602.5)	(2532.3)	(63.14)	(55.36)
R^2	0.031	0.268	0.091	0.050	0.095	0.167	0.051	0.015
Adjusted R^2	0.024	0.263	0.084	0.043	0.088	0.161	0.043	0.007
Pseudo R^2								
Observations	2420	2420	2420	2420	2420	2420	2420	2420

*Notes: *** p<0.01, ** p<0.05, * p<0.1.*

Supplementary Materials

Supplementary Appendix 1: The three "cluster" models of DoF, ACI Agrolink, and BSFF

	DoF	ACI Agrolink	BSFF
Stated goals/selfdescription	Intensive production	Strengthening backward market linkage via a cluster *contract farming* model Improve capacity utilization; secure volumes, help other businesses	Increasing production and ensuring quality through clusterbased improved production methods and access to finance
Description of the model	Matched grant for ponddeepening and aggregating a cluster of ponds, uniform practices, buying and selling at one time, intensification, traceability, eventually certification.	2 phases originating (1 year) and graduating phase; Cluster approach, arrangement of inputs (feed/seed) on credit for some, knowledge inputs; currently input credit, no contracts yet	Cluster approach, deepening ponds, nursing before stocking, and using SPF PL; clusterbased access to finance
Districts / study sites	Khulna, Satkhira, and Bagerhat districts	Kaliganj upazila (Satkhira district)	Dumuria upazila (Khulna district) and Bagerhat district
Average pond size/farm size	30 decimals to 1.5 acres – eligibility restricted to <=1.5 acres	Small farmers, with average pond sizes of 13 acres; in future will target larger farmers	Small farmers
Selection approach	Union leaders /influential people to identify 2025 contiguous ponds, "willing", common water source – automatic disqualification if less then 20 ponds and large farmers.	Close to the plant factory, 510 miles, surrounding area; contiguous ponds, willingness to follow input technology, commit to follow process and buyback. leased	Farmer list developed by BSFF
Components			
Pond deepening	At farmer's own cost; compulsory	At farmers' own cost pond deepening/embankment increased	At farmers' own cost
SPFPL	SPFPL mandated. First year, free supply of SPFPL, through an arrangement with hatcheriesDeshbangla	Arranged SPFPL for farmers through MKA hatchery. ACI will have its own nursery, for 46 days and then sell to; but farmers pay for it	SPFPL 'given' to farmers
Species	Bagda/Golda	Bagda	Bagda

	DoF	ACI Agrolink	BSFF
Polyculture	Monoculture, coordinated stocking and harvest in a cluster	Single stocking 150 PL/decimal – 3 harvesting cycles /year, monoculture; but 3rd quarter release white fish, etc.	Monoculture
Feed	First year feed supply is free	Provide feed but farmer pays for it some take it on credit); ACI Animal Health is a feed producer as well	Unclear
Aerators	No	No	No
Traceability	Community mobilizers record data on Source Tracedeveloped android ap.	Planned. Already have traceability apps.	Plan to implement etraceability through an app developed under AIN/SAFETI projects
Market linkage	Working on getting processors to directly procure from the cluster	ACI Link will procure; 1 cluster has a landing station ACI team gets it 2nd option/ supplier working with us the supplier 3rd one: farmer can come to the factory gate	Planned procurement by processors such as Gemini and Fahim Seafoods
Credit arrangements	Matching grant – farmer finances pond deepening, input credit (seed and feed) for the first year for farmers	Inputs as advance credit from MKA and ACI settles with MKA; some farmers also procure from MKA directly and pay with cash	Credit support per cluster by banks (such as UCB, Mercantile Bank), facilitated by BSFF
Insurance	None	Shrimp insurance climate shocks in partnership with Green Delta Insurance: covers excess rainfall, temperature and WSD	None
Training and extension	Provided by community mobilizers of Solidaridad	ACI staff (consultant), employee based on the module	BSFF staff
Consortium partners	SourceTrace, Solidaridad, Deshbangla Hatcheries	DFCD, SNG ACI Agrolink, ACI Animal Health	Current Aquaculture Improvers Program supported by WorldFish for 8 months

Source: Authors.

- DoF uses a "cluster" approach, organizes groups of 2025 farmers with contiguous shrimp ponds and a common water source into a cluster, requires that farmers invest in deepening ponds, provides subsidized SPFPL and feed for one year, ensures that farmers stock and harvest the pond simultaneously, and facilitates sale of the harvest from the cluster directly to a processor.

- ACI Agrolink too follows a "cluster" approach, organizing groups of 2025 farmers with contiguous ponds into a cluster with direct procurement of shrimp by ACI Agrolink to process. ACI Agrolink also advances input credit to some shrimp farmers who buy ACI Animal Health's feed, bundles insurance, and aims to have written contracts with clusters to support the buyback of shrimp.
- BSFF works closely with WorldFish to form clusters. Shrimp farmers commit to monoculture and are provided SPFPL, clusterlevel credit from designated banks and a buyback arranged with specific processing firms.

A distinguishing feature of the DoF intervention, a public sector initiative, is the subsidization of inputs akin to a matching grant, versus that of the private sector processors who invest in the relationship without grants or subsidies. BSFF facilitates credit and apparently subsidizes SPFPL alone. All three interventions are in their early stages, providing a suitable context for researching impacts. Despite the challenges these pose for rigorous impact evaluation, we believe that studying these different models can produce meaningful and compelling inputs into policy and business decisions.

Supplementary Appendix 2: Power calculations

Our research is constrained by the current scale of interventions which in turn limit our sample size. We compute the minimum detectable effect (MDE) size, focusing on the slope coefficient of the treatment variable (i.e. whether or not the respondent is a cluster farmer), in the context of a quasi-experiment. We use a somewhat stringent standard of 0.9 power, 1% significance and do not use covariates in the current model. Our main objective is to see if, given the sample size that is feasible for each of the four models, what effect sizes would we be able to detect for the key outcomes of interest. In particular, given the aggregable nature of our impact evaluation, will the analysis be powered to support inference for each model.

We use survey data collected by a member of the research team in 201819 to benchmark the mean (or proportion, as the case may be) and standard deviation of a subset of the outcome variables. For some variables, for example the proportion that practice monoculture, given that the survey data reported none, we dropped them from our power analysis.

The key results are provided in Box 1.

For the pooled sample, we can detect small effects. Other than net income per hectare of pond, where the increases have to be about 40% for us to be able to detect, for most other variables we are able to smaller changes. One caveat here is that we did not trim the sample data nor corrected for outliers. Hence, the MDE is higher than it would have been had we accounted for this.

We find that we are less able to comment/infer impacts. For two of the four models, our sample size is adequate to detect small impacts but for two others, we do not have adequate power. Hence should we find no impacts in our data, we cannot claim that we do not reject the null of no impacts.

Box 1: Power analysis at a glance

Pooled sample (MDE = 0.22 standard deviations)

- 7.9 and 3.8 percentage points increase in SPFPL and PCRPL
- 12 ppt increase in commercial feed use
- 30% increase in all species yield (kg/ha) and 31% in unit value (taka/kg); 39% increase in shrimp yield and 4% increase in shrimp price Taka/kg
- Net incomes per ha: ~40% increases with outliers
- 2.9% increase in MDDS (dietary diversity)

Model-specific MDE: 0.40.5 standard deviations

- Two of the four models amenable to model specific IE.

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