sustainability

Expanded Technical Appendix

Propensity Score Matching (PSM)

If a household is participating in fish farming ($F = 1$), the expected average outcome is $E(Y_1|F = 1)$ and the counterfactual situation when the household is not participating in fish farming is $E(Y_0|F = 1)$. However, the issue here is that the counterfactual is unobservable. We can, however, observe the outcome of a non-fish farming household ($F = 0$), $E(Y_0|F = 0)$. Thus, in estimating the ATT, we use the following estimation:

$$\begin{aligned} ATT &= E(Y_1 - Y_0|F = 1) \\ &= E(Y_1|F = 1) - E(Y_0|F = 1) \end{aligned} \tag{1}$$

The interest here is not really in $E(Y_0|F = 0)$ but in $E(Y_0|F = 1)$. However, $E(Y_0|F = 1)$ is not observed, so PSM uses the observed mean of the outcome variable of non-fish farming households that are similar to the fish farming households in the observed characteristics, i.e., it uses $E(Y_0|F = 0)$ to estimate $E(Y_0|F = 1)$, estimated as:

$$E(Y_0|F = 1) - E(Y_0|F = 0) = 0 \tag{2}$$

Equation (2) ensures that there is no bias from self-selection in the ATT. For equation (2) to be fulfilled, two conditions must be in place: conditional dependence, equation (5)[1] and common support, equation (3)[2]. The first condition requires that the outcome variable is independent of the treatment variable with the observed covariates, expressed as:

$$Y_1, Y_0 \perp F|X \tag{3}$$

The second condition of common support ensures that each individual household has a positive probability of either being a fish farming household or not, and is expressed as:

$$0 < \Pr(F = 1|X) < 1 \tag{4}$$

With both conditions in place, the ATT is estimated as follows:

$$\begin{aligned} ATT &= E(Y_1 - Y_0|F = 1) \\ &= E\big[E\big(Y_1 - Y_0\big|F = 1, P(X)\big)\big] \\ &= E\Big[E\big(Y_1\big|F = 1, P(X)\big) - E\big[E\big(Y_0\big|F = 1, P(X)\big)\big|F = 1\big]\Big] \\ &= E\Big[E\big(Y_1\big|F = 1, P(X)\big) - E\big[E\big(Y_0\big|F = 0, P(X)\big)\big|F = 1\big]\Big] \end{aligned} \tag{5}$$

Matching Algorithms

After applying the logit regression to estimate the propensity scores, we now must match a fish farming household to a non-fish farming household. The most common matching algorithm is the greedy matching, which includes Mahalanobis Metric, nearest neighbor, caliper, nearest neighbor within caliper and nearest available Mahalanobis metric matching within calipers defined by the propensity score. Each of these have their strengths, weaknesses and appropriateness depending on the data available.

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[1] The equation means any effect from participating in fish farming on household dietary diversity is because of the observed covariates; so that the differences in dietary diversity for fish farming and non-fish farming households is purely random.

[2] The common support condition eliminates the occurrence of perfect prediction. With both conditions in place, the assumption of 'strong ignorability" is invoked.

Robustness Test (Rosenbaum Sensitivity Analysis)

The estimates of the PSM cannot be said to be entirely unbiased and random if there is an unobserved covariate(s) influencing the assignment to treatment. However, if there are unobserved covariates that affect the assignment to treatment but not the outcome, the robustness of the estimation is not called into question.

Testing the Quality of Matching (Covariate Balancing)

The idea behind matching is to create a control group that is statistically like the treated group in order to have an unbiased estimate of the average effect of the treatment on the treated (ATT). The quality of how well the covariates match up or balance is tested using the standardized bias (SB) between the treated and control groups [38]. The balancing test is carried out on the equality of the means on p-scores and the covariates. Because matching is done only on the observed covariates in PSM, there might still be some bias present post-estimation from unobserved covariates.

Validation of FCS as a Food Security Indicator

Dietary diversity is an indication of the number of different food groups that a household purchases and consumes over a period, either 24 hours or seven days. It is a proxy for food security; in order to justify its use, we must validate it using variables that explain the food security situation in Ghana.

For FCS to be a valid measure of food security, it must be able to capture all four pillars of food security namely; accessibility, availability, utilization and stability [S2 and S1]. Household per capita income and wealth index have been used as food security indicators, and the strength of correlation is high to validate FCS as a proxy measure of food security. From Table A1, FCS is correlated at the five percent level with household income (0.036), wealth index squared (0.051) and per capita household income (0.04) approximately. Even though the magnitudes are lower compared to those obtained by [S2], they are still significant, making FCS a valid proxy measure for food security for our study.

Table 1. Correlation of FCS with other Food Security Indicators.

Variable	FCS	Wealth index squared	Per capita household income	Household income
FCS	1.000			
Wealth index squared	0.051*	1.000		
Per capita household income	0.040*	0.012	1.000	
Household income	0.036*	-0.050*	0.894*	1.000

* 5 percent significance level.

Effect of Income Diversification on Household Nutritional Quality

Income diversification is another way of improving household food security. It helps to reduce risks associated with the households' ability to access food. Our results imply that household income reduced the probability of a household to engage in fish farming. Therefore, the ability of the household to increase its probability of access to food can be increased if household income sources are diversified. We simulate three different scenarios with three different income sources: non-fish farming income only, income from fish farming plus non-fish farming (diversified income) and income form only fish farming. Results of these simulations are presented in Table A2.

Table 2. Predicted Probabilities of achieving higher food security status with income diversification.

Variables	Predicted prob.
poor#non-fish income	0.004***
	(0.01)
poor#fish income	0.004***

	(0.00)
poor#diverse income	0.003***
	(0.00)
borderline#non-fish income	0.142***
	(0.01)
borderline#fish income	0.133***
	(0.02)
borderline#diverse income	0.112***
	(0.01)
Acceptable#non-fish income	0.854***
	(0.01)
Acceptable#fish income	0.863***
	(0.02)
Acceptable#diverse income	0.885***
	(0.01)
Observations	4,000

Standard errors in parentheses; *** $p<0.01$, ** $p<0.05$, * $p<0.1$; NOTE: All regressors are at their mean value.

We observe that the probability of households increasing their food security status increases with a diversified income source (89 percent), with only income from fish farming (86 percent) and 85 percent with non-fish income. The probabilities of being food insecure are very low; 0.004 for food poor with no income from fish farming, 0.004 with income from fish farming and 0.003 with a diversified income source; all are significant at the 1 percent level. These outcomes imply that household's probability of attaining high nutritional quality increases with fish farming as an extra source of income assuming a household is engaged in other non-fish farming related ventures.

References

1. S1. Hoddinott, J. and Yohannes, Y. 2002. "Dietary Diversity as a Food Security Indicator." Food and Nutrition Technical Assistance Project (FANTA).
2. S2. Kennedy, G., A. Berardo, C. Papavero, P. Horjus, T. Ballard, MC. Dop, J. Delbaere and D. Brower. 2010. "Proxy Measures of Household Food Consumption for Food Security Assessment and Surveillance: Comparison of eth Household Dietary Diversity and Food Consumption Scores." Public Health Nutrition Vol 1, No. 12, pp.2010-2018.