

Article

Assessment of Household Food Security in Fish Farming Communities in Ghana

Akua S. Akuffo * and Kwamena K. Quagrainie

Department of Agricultural Economics, Purdue University, West Lafayette, USA; *asakuffo@gmail.com.
2051 N Avon Avenue. Avon, IN 46123, USA; kquagrai@purdue.edu. 403 W. State Street, West Lafayette, IN
47907, USA

Abstract: The Government of Ghana and international NGOs have been encouraging adoption of fish farming to alleviate poverty and food insecurity through training workshops, financial contributions and creation of a fisheries ministry. Nevertheless, there is no study on how these efforts have influenced the household's welfare particularly their nutritional quality. Based on this, our objective is to identify the direction and impact pathways of fish farming on household nutritional quality. We hypothesize that engaging in fish farming will increase steady income flow and access to fish for the household's direct consumption. We adopted the Propensity Score Matching (PSM) approach in a logit framework to achieve this objective and address the endogeneity from the bias of self-selection by creating a statistically similar-looking control group. The results suggest that fish farming households have higher nutritional quality and frequency of food consumed than the non-fish farming households through direct consumption. The probability of adopting fish farming increases with wealth, location, ecological zone and household size but decreases with household income per capita. The average effect of adopting fish farming on household nutritional quality is 15.5 points. Policies that encourage women to engage in not only fish processing, but production as well are advised.

Keywords: Food security; fish farming; Propensity Score Matching; Food Consumption Score (FCS), Ghana

1. Introduction

Does fish farming influence a household's food security/nutritional quality in Ghana? If it does, in what ways? A country's socioeconomic development depends on the welfare of its citizens, particularly their health. Fish farming is becoming very popular in developing countries because of its ability to improve the welfare of particularly less wealthy and landless-food insecure households through employment, income generation and nutrition from direct consumption [1]. In Africa and Asia, several developmental interventions related to fish consumption, aquaculture, and capture fisheries have aimed at improving the nutritional status of households through direct dietary intake, production and increase in household income [1]. In addition to the provision of food, fish farming has the potential to contribute to the Millennium Development Goals (MDGs) of reducing poverty and halving hunger through creation of employment, community development [2] and consequently has been adopted by many Asian and African national governments.

In 2013, the Ministry of Fisheries and Aquaculture Development was created in Ghana out of the Ministry of Food and Agriculture to give more emphasis and support to the industry. The ministry with support from the Food and Agriculture Organization (FAO) developed a Ghana National Aquaculture Development Plan (GNADP) to increase profitability and production up to 100,000 metric tons by 2016 [3]. The GNADP also aimed at improving the capacity for fish farmers through trainings in best management practices and feed formulation [4]. Similar capacity trainings were also conducted by the United States Agency for International Development (USAID), UK's

Department for International Development (DFID), and the New Partnership for Africa's Development (NEPAD). The World Bank in collaboration with the Government of Ghana (GoG) also developed the Ghana Fisheries and Aquaculture Development Plan – GFADP [5]. The GFADP serves as a roadmap by which aquaculture will contribute to poverty alleviation, food and nutritional security, employment generation, increased income and economic development as part of the government's efforts to reduce poverty under the Ghana Poverty Reduction Strategy II (GPRS II) [4] and the Millennium Development Goals. The Ghana Association of Women Entrepreneurs (GAWE) and Rural Wealth (RW) are among the few local non-governmental organizations that are actively engaged in aquaculture projects [6].

The level of production from aquaculture in Ghana increased from approximately 19,092 metric tons in 2011 to 44,515 metric tons in 2015 [7]. From 2009 to 2012, cage aquaculture production experienced an increase from 4,912 metric tons to 24,249 metric tons [6, 8].

The food insecurity situation in Ghana is more of access and stability rather than availability. Food insecurity is a national issue in Ghana due to widespread poverty. The problem exists in both rural and urban areas with the rural areas being the most affected. Ghana's food insecurity is heightened by irregularities in the seasons and production. The latter is highly dependent on rainfall, high food prices coupled with low incomes at the household level [9]. The most food insecure regions in Ghana are the three Northern regions and the least food insecure areas are Greater Accra and the Western regions [10].

The concept of food security is measured in so many ways due to lack of proper assessment of the different aspects of it [11]. In estimating the impact of technology adoption on food security, for example, proxies for food security include the use of household income and expenditure; others have also tried to use production measures [12]. Synthetic poverty indices have been used in some studies [13]. All these measures conclude that the adoption of an improved practice has a positive impact on the welfare of Sub-Saharan African (SSA) countries and contributes to the reduction of poverty. These measures however have limitations; mainly on how much impact can be captured with monetary and production [11]. Other indicators developed and validated by the World Food Program (WFP) and other organizations include Coping Strategies Index (CSI), Reduced Coping Strategies Index (rCSI), Household Food Insecurity and Access Scale (HFIAS), the Household Hunger Scale (HHS), Food Consumption Score (FCS), Household Dietary Diversity Scale (HDDS) and a self-assessed measure of food security (SAFS) [14].

Several factors that are critical to the nutritional decisions made by the household are the focus in studies of household nutrition. The common factors identified in the literature are income, tastes, education, family size and composition, and market price [15]. In Bangladesh, it was observed that even though fish is quite expensive, consumption in small quantities makes a significant difference in contributing to the nutritional quality of the diets of poor people [16]. In the central region of Malawi, a study of fish farming and non-fish farming households over a period of four weeks revealed no significant differences between households in terms of nutritional status. Fish farming households cultured the fish mainly for selling purposes and not for consumption; fish consumption by producing households was very low [17].

A study was carried out to evaluate the influence of food insecurity on the malnutrition of children. Using a sample of children aged 6-36 months residing in both rural and urban areas of Tamale in northern Ghana, access of households to food was measured using the Household Food Insecurity and Access Scale (HFIAS), Food Consumption Score (FCS), and Household Dietary Diversity Score (HDDS) [18]. The determinants that influenced malnutrition of children included wealth index, body mass index of the mother, mother's educational level, the area of residence and access to portable water. A study in Ghana revealed that even though poorer households had successfully adopted aquaculture, the impacts could not be determined from their livelihoods compared to non-poor fish farming households [19]. The author explained that the adoption of aquaculture was dependent on household characteristics and the level of knowledge about aquaculture and concluded that the level of impact is largely dependent on the socio-economic status of the household as well as institutional and infrastructural resources available to them.

This paper examined the impact of fish farming within the framework of an agricultural innovation since it involves the use of technology, which deviates from the traditional farming activities. The impact of a technology intervention on income, expenditure and other components of food security may be positive or negative for the household. We use data on all ten regions of Ghana, but most fish farmers are located along the Volta Lake in the Eastern, Brong Ahafo and Volta regions making the decision to engage not random.

Even though fish farming has become an integral part of the efforts of the Ghanaian Government to reduce poverty and improve food security, there is no study on the assessment of how participating in fish farming impact the nutritional quality of farming households. The main objective is to identify the direction of impact and the pathway(s) of fish farming on household nutritional quality. We hypothesize that fish farming households have more diversified diets than non-fish farming households. The assumption is that engaging in fish farming will increase steady income flow and access to fish for household's consumption. Households will then be able to purchase and consume more diverse and nutritious food items, particularly vegetables, meat, dairy and fresh fruits.

The measure of food security is proxied by the World Food Program's Food Consumption Score (FCS). The correlation between fish farming and food security is estimated using the Average Treatment on the Treated (ATT) under the Propensity Score Matching (PSM) framework. We address three main gaps in the literature on the impact of fish farming on household welfare. First, most of the impact studies have focused mainly on agricultural households without separating them into different sectors including fisheries. Secondly, the household welfare measures have been on poverty alleviation and income growth and very rarely on nutritional improvements. Lastly, we address the lack of assessment of the counterfactual situation if the treatment had not been received, i.e., if fish farming had not been adopted. We use a non-parametric matching approach, the Propensity Score Matching (PSM) to address this issue.

2. Materials and Method

The decision for any individual or household to take up fish farming as an occupation is in most cases unknown to the researcher. Consequently, the attempt to assess the magnitude or ways in which fish farming contributes to a household's nutritional quality is not straight forward, especially in the absence of pre-participation data. The literature refers to this as self-selection. Regression estimates will either have an upward or downward bias. Alternative ways that address the bias include the Heckman Two-Step Approach, one of the popular methods that uses the Inverse-Mills ratio as an explanatory variable in the outcome equation. The shortcoming of the approach is the normal distribution assumption made about the unobserved variables. Another popular alternative is the Instrumental Variable (IV) approach because it deals with both hidden and overt biases. However, it is difficult to find a variable, which is correlated with the decision variable but uncorrelated with the outcome variable, which makes the approach unattractive. Several instruments were identified and tested¹ in this study but none was found to be suitable.

2.1. Propensity Score Matching (PSM)

Propensity Score Matching (PSM) is a quasi-experimental approach. PSM reduces the estimation bias in measuring the impact of a treatment with observational data [20]. The non-random assignment of the treatment and control groups introduces a selection bias. PSM involves mainly two stages; estimating the decision to adopt fish farming in a logit regression with fish farming as a function of household observable characteristics. The second stage is the determination of the impact of the adoption decision on household nutritional quality, the outcome variable using the average treatment effect. The impact of the adoption decision on the outcome variable is estimated by

¹ Omitted variable test, Oster's test for omitted variables, Durbin-Wu- Hausman test.

calculating the net impact of adoption on the household's nutritional quality [8]. The following segments give details about the two stages of the PSM. The basic set up for PSM is;

$$Y_1 = \beta_1 X + \varepsilon_1$$

$$Y_0 = \beta_0 X + \varepsilon_0 \quad (1)$$

where Y_1 is the outcome variable for the treated group, that is fish farming households; Y_0 is the outcome variable for the control group, that is non-fish farming households; X is the vector of observed characteristics for both control and treated groups, ε_1 and ε_0 represent the error terms assumed to be exogenous of the vector of observed covariates. The ideal case for such an impact study is to make a comparison for the same individual with and without the treatment. However, it is not possible in this study due to the absence of a pre-participation data of the individuals. One way to deal with the absence of pre-participation data is to do a counterfactual analysis [21]. The practical approach is to have an "observed" outcome Y_1 if an individual is a fish farmer and the counterfactual or control Y_0 outcome that would have happened if the individual were not a fish farmer. The difference between what happened and what would have happened is expressed as:

$$\text{net impact of adoption} = Y_1 - Y_0 \quad (2)$$

Our interest here is the correlation between participation in fish farming denoted by F and the household's dietary diversity. Following Rubin and Rosenbaum, we estimate the Average Treatment on the Treated (ATT) using two matching algorithms; nearest neighbor (NNM) and kernel-based matching [22, 23, 24]. After the matching, the bias ratio of the covariates is tested using a Likelihood ratio test and pseudo- R^2 . The pseudo- R^2 should be low, and we should reject the Likelihood ratio test for joint significance. The Rosenbaum Sensitivity analysis [25] whether unobserved covariates are influencing our estimates as this will affect our final inferences².

3. Data

Data for the analysis were obtained from the 2013 Ghana Living Standards Survey (GLSS6) [26]. The survey solicited information on a range of factors including demographic, socioeconomic, individual, household characteristics and health issues. The data has information on a total of 16,772 households from all ten regions of Ghana, but we used approximately 4011 household information that included 144 fish-farming household. The sample size was determined after using influence diagnostics³ to identify observations that influence our variance and everything else.

3.1. Outcome and Treatment Variables

Food Consumption Score (FCS): The FCS is used as a 'validated proxy measure' for food security [14]. FCS was developed with funding from USAID under the Food and Nutrition Technical Assistance (FANTA) project and the World Food Program (WFP) promotes its use. It is a weighted measure of dietary diversity and constructed as:

² Details shown in supplementary material.

³ Influential diagnostics will generally produce large studentized residuals (rstudent) for outliers.

Using rstudent thresholds, observations were dropped if their rstudent values were outside the range of $2 \geq r \leq -2$.

$$FCS = \sum y_i f_i \quad (3)$$

Where y_i is the different food groups and i represents cereals, roots & tubers, vegetables, fruits, meat/poultry, eggs, seafood/fish, milk, legumes, sugar, oil/fat, condiments; f_i is the consumption frequency of that food group over the past week or month (Table 1). We hypothesize that fish farming households have higher dietary diversity and food security than the non-fish farming households. The assumption is that engaging in fish farming is expected to have a positive and direct impact on household income. Households will then be able to purchase and consume more diverse and nutritious food items, particularly vegetables, meat, dairy and fresh fruits.

In identifying the food security status of a household, the thresholds from the WFP are used. FCS has two different range values depending on the frequency of sugar and oil consumed by the household. Households with FCS of 0 – 21 are categorized as having poor food consumption, those within 21.5 – 35 are classified as borderline food consumption, and above 35 categorized as having acceptable food consumption. According to the WFP, the FCS value can be adjusted in the presence of evidence [27]. Different countries have different thresholds based on their situation. For example, in Laos and Haiti, the threshold levels are much higher for daily edible oil and sugar consumers. The situation in Laos and Haiti is like our sample therefore; we adopted the threshold levels used in Laos and Haiti.

Fish farming: This is a binary variable representing whether the household is engaged in fish farming. It is the dependent variable in the logit regression in PSM. It is assumed that households engaged in fish farming consume the fish they harvest from their own ponds and obtain income from selling some of the fish. The variable is expected to have a positive correlation with food security.

Table 1. WFP Food Groups and Weights used in Calculating Food Consumption Score.

Food Items	Food Groups	Weights
Maize, maize porridge, rice, sorghum, millet, pasta, bread, other cereals, Cassava, potatoes & sweet potatoes	Cereals & Tubers	2
Beans, peas, groundnuts, cashew nuts & other nuts	Pulses	3
Vegetables, leave & fruits	Vegetables & fruits	1
Red meat, poultry, eggs, fish	Meat & fish	4
Milk, yoghurt & other dairy products	Milk	4
Sugar & sugar products	Sugar	0.5
Oils, fat & butter	Oil	0.5
Condiments	Condiments	0

Data at the household level provides information on the characteristics and location of the household. This study uses data on the following demographics of the household head: years of education, marital status, sex, employment status, and age. Additional information on the household's location and economic status are proxied by ecological zone, wealth index, household size and monthly income in Ghana cedis (GHS).

4. Results and Discussion

4.1. Summary Statistics

The average FCS is 57.5 units with fish farming households on average having approximately 68.7 while non-fish farming households have a consumption score of approximately 57.3 (Table 2).

Table 2. Summary Statistics.

	Pooled	Sd	FFHH mean	nFFHH mean	FFHH sd	nFFHH sd	t-test (pvalues)
FCS	57.49	13.67	68.74	57.33	14.98	13.38	0.00
Wealthindex_sqr	1.56	2.66	1.58	1.56	2.78	2.65	0.01
Wealth index	-0.19	1.26	-0.21	-0.19	1.47	1.25	0.00

Education	10.28	6.12	7.00	10.33	6.62	6.09	0.00
Age	45.16	12.08	44.79	45.16	12.32	12.07	0.18
Peri-urban	0.05	0.27	0.03	0.05	0.41	0.26	0.00
Marital status	0.77	0.39	0.93	0.77	0.26	0.39	0.00
Employed	0.99	0.10	1.00	0.99	0.17	0.10	0.04
Male	0.81	0.36	1.00	0.81	0.27	0.37	0.01
Ecology	2.27	0.64	2.65	2.26	0.63	0.64	0.00
HHinc_cap	248.37	545.82	34.35	251.40	124.56	554.16	0.00
HHsize	5.48	3.26	8.39	5.44	4.87	3.16	0.00
Techsupport	0.49	0.50	0.49	0.49	0.49	0.50	0.00

Fish farming households also have a higher absolute wealth index values than non-fish farming of 0.21 and 0.19 respectively (Table 3). Only 4.7 percent of the sample is in the peri-urban area, with fish farming households making up 3.2 percent and non-fish farming households, 4.8 percent (Table 3). The average household size for a fish farming household is 8 compared to 5 for the non-fish farming household.

The control group is mostly agricultural households. On the average approximately 49 percent of our sample receives some type of extension assistance. The average income per capita for fish farming households is low (34.35 GHS) compared to non-fish farming households (251.40 GHS). The same pattern is observed in the average years of education, 7 years for fish farming household heads and 10 years for non-fish farming household heads. The fish farming households differed significantly in most of the household characteristics from non-fish farming households except for age which was highly insignificant (Table 3).

Table 3. Results showing Factors that Influence Fish Farming Adoption Decision.

Variables	Coefficient (SE)	Average marginal effects	Odds ratio
Wealth index squared	0.382 (0.05)***	0.012 (0.00)**	1.465
Wealth index	0.802 (0.107)	0.029 (0.00)***	2.230
Education	-0.024 (0.02)	-0.001 (0.00)	0.976
Age	0.001 (0.01)	0.000 (0.00)	1.002
Peri-urban	0.953 (0.23)***	0.030 (0.01)***	2.593
Married	0.074 (0.41)	0.002 (0.01)	1.077
Employed	-0.214 (0.59)	-0.007 (0.02)	0.807
Sex	0.608 (0.39)	0.019 (0.01)	1.836
Ecology	0.319 (0.17)*	0.010 (0.01)*	1.376
Income/capita	-0.003 (0.00)***	-0.000 (0.00)***	0.997
Household size	0.099 (0.02)***	0.003 (0.00)***	1.104
Constant	-5.431 (0.90)***		0.004

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

4.2.: Factors Influencing the Adoption of Fish Farming at the Household Level

Table 3 shows the coefficients, average marginal effects and the odds ratio with respect to the outcome variable, FCS. Apart from education, sex, age, employment status and marital status of the household head that were not significant, the rest of the covariates were significant.

The marginal effect for peri-urban is positive and significant at the 1 percent level (Table 3). The implication here is that, a household's adoption decision increases by 3.0 percent with an increase in proximity to or residence in a peri-urban area. Most of the fish farms in Ghana are in peri-urban areas. These areas tend to have the land size suitable for agriculture, amenities to enhance its success such as nearness to market centers to take advantage of competitive prices and low transportation cost particularly for smallholder farmers [19, 28].

Residents of peri-urban localities also have higher probability of finding other off-farm income-generating opportunities [29], access to an energy source (electricity) and increased access to technical support as the extension officers are hardly ever willing to travel to rural areas. Most of these areas are commonly located in the Ashanti, Brong Ahafo, Western, Greater Accra and Eastern regions of Ghana.

Most studies on the factors that influence the decision to adopt an agricultural-related technology use a sample in the rural areas, e.g. [30, 24, 31, 32, 33]. Our results cannot be directly compared to these studies because they focused on rural and peri-urban household market participation and the factors that influence them. However, some studies have concluded that households in the peri-urban areas had greater access to information as well as amenities making the decision to participate much easier compared to those in the rural areas.

The total average marginal effect of wealth on fish adoption is 4.1 percentage points (1.2+2.9). Thus, implies that on the margin, 1 percent increase in wealth increases the probability to adopt fish farming by 4.1 percentage points at the 1 percent level. The probability to adopt fish farming increases the wealthier a household gets. Studies by [34] and [35] all found similar results while [36] reported a negative but significant coefficient in Niger.

The wealth index, a proxy measure of the long-term economic status of the household is positive as we hypothesized. Wealth is a strong indicator of the economic situation of the household and a good predictor of the household's attitude toward technology adoption. A wealthy household can assume risks associated with the technology, has greater access to resources, credit and diverse income sources, which increases their probability of adopting new technology, especially one that is capital intensive.

The ecological location of the household head increases the possibility of adoption at the 5 percent level (Table 3). The marginal effect of the ecological zone means that the probability of the household adopting fish farming increases by 1.0 percentage point with a 1 percent move toward the inland regions. Similar results are reported by [22, 37]. However, other studies such as [38] and [11] found contradictory results. Ghana has three main ecological zones, namely savannah found in the Brong Ahafo, Northern, Upper East and West regions, forest found in the Western, Central, Volta, Eastern, Ashanti and parts of the Brong Ahafo regions, and coastal found in the southern parts of Greater Accra, Central, Western and Volta regions. Those in the coastal regions are mainly engaged in marine fishing due to the proximity to the sea.

The results suggest that fish farming will positively influence the nutritional quality of households in the forest and savannah regions. The forest regions have long rainy seasons and water resources to support fish farming. Due to the dry nature of the savannah ecological zone, agriculture is dependent more on irrigation. There are existing irrigation schemes around the country, including Ve, Tono, in the Upper East and Golinga, Ligba and Bontanga and Northern regions, which support rice and vegetable production [39]. These schemes can be good sources of water for cage culture which requires minimum investment and covers a segment of a pond.

From Table 3, the size of the household also positively influences the probability of adoption at the 1 percent level. The probability of adopting fish farming increases by 0.3 percentage points on the margin when the household size grows by one person. Similar results were also recorded by [40, 41] in their studies. However, contrary results identified by [42, 42, 44]. Labor is a costly input in agriculture in Ghana making family members the main source of labor for most subsistence fish farming households.

4.3.: Impact of Fish Farming on Household Nutritional Quality

In order to estimate the impact fish farming has on household nutritional quality, the average treatment effect on the treated (ATT) was calculated after matching, and the results are shown in Table 4. All matching algorithms show similar results that on average, adopting fish farming significantly increases the nutritional quality of households as measured by the food consumption score. The average improvement in nutritional quality is between 13.9 and 15.5 points. This increase in nutritional quality can be translated food wise into consuming fish at least twice a week, roots/tuber or cereals, pulses and legumes once a week, fats and oils or sugar and sugar products once a week and vegetables or fruits twice a week. Similar improvements were noticed in other studies but not of similar magnitudes [45, 46].

Table 4. Impact of Fish Farming Participation on Household Food Security.

Variables	Matching Algorithm	Treatment	Control	ATT	BSE	t-stat	FFHH	nFHHH
FCS	NNM							
	(1)	69.77	54.23	15.54	1.71	9.11	143	3867
	NNM							
	(5)	69.77	54.28	15.54	1.44	10.78	143	3867
	KBM							
	(0.03)	69.77	55.30	13.86	1.38	10.31	143	3867
	KBM							
	(0.06)	69.50	55.64	13.86	1.34	10.35	143	3867

BSE = Bootstrapped standard errors with 100 replications.

There are several pathways that have been identified through which agricultural interventions influence the nutrition of a household [43, 44, 45]. The major pathway through which fish farming contributes to poverty alleviation and economic development in Ghana is the multiplier effect [19]. However, from our findings, the effect here is direct consumption. We conclude therefore that a household that participates in fish farming has a higher probability of achieving higher nutritional quality because of increased access and availability.

4.4.: Test for selection bias

The results to check the matching procedure are shown in Table 5. The results show a significant percentage reduction in biases as seen in Table 5 and most importantly after matching, no significant differences are seen between fish farming and non-fish farming households for any of the covariates.

Table 5. Tests for Selection Bias after Matching.

Variables	Matched sample		%Bias	Bias Reduced	t-test p-value
	Treated	Control			
Wealth index squared	2.16		10.8	47.4	0.48
	1.86				
Wealth index	0.12		1.0	95.8	0.94
	0.11				
Education	7.76		15.7	47.4	0.18
	6.76				
Age	45.99		-2.1	82.8	0.88
	46.24				
Peri-urban	0.21		-8.2	79.5	0.57
	0.24				
Married	0.93		2.1	94.2	0.82
	0.92				
Employed	0.97		-10.3	22.9	0.41
	0.99				

Sex		0.92 0.93		-2.2	91.5	0.82
Ecology		2.62 2.57		7.8	80.4	0.50
Income/capita	63.09		56.01	1.8	96.2	0.61
Household size		7.69 8.36		-16.3	68.8	0.24

After the matching procedure, the pseudo- R^2 and the likelihood ratio reduced in magnitude and were insignificant (Table 6). This finding supports the point that there are no significant differences in terms of the relevant covariates between a fish farming and a non-fish farming household.

The test of joint significant effect of the covariates was rejected post matching with an insignificant likelihood ratio in all four different versions of the nearest neighbour and kernel-based approaches. The mean bias reductions according to the literature is acceptable when it is below 20 percent. From Table 6, all our reductions are below 11 percent. This is an indication of a good matching procedure.

Table 6. Statistical Tests to Evaluate the Matching Procedure.

Matching Algorithm	R^2 -before	R^2 -after	LR-before	LR after	Chi ² -before	Chi ² -after	MSB-before	MSB-after
NNM	0.15	0.01	189.05	4.54	0.00	0.95	30.90	7.10
(1)								
NNM	0.15	0.01	189.05	5.50	0.00	0.99	30.90	5.50
(5)								
KBM	0.15	0.01	189.05	3.22	0.00	0.99	30.90	3.50
(0.03)								
KBM	0.15	0.03	189.05	10.79	0.00	0.46	30.90	8.10
(0.06)								

MSB: Mean squared bias.

4.5.: Testing for hidden bias post estimation

The presence of bias from observed covariates was tested using the Rosenbaum sensitivity analysis. Under the assumption that the true treatment effect was underestimated (sig-), the bounds show that the results are highly unresponsive to the presence of hidden bias. Results are in Table 7.

Table 7. Sensitivity analysis with Rosenbaum Bounds.

Gamma	Sig+	Sig-
1	4.1e-14	4.1e-14
1.1	1.4e-12	7.8e-16
1.2	2.8e-11	0
1.3	3.5e-10	0
1.4	2.9e-09	0
1.5	1.8e-08	0
1.6	9.2e-08	0
1.7	3.7e-07	0
1.8	1.3e-06	0
1.9	3.9e-06	0
2.0	0.00001	0

5. Post-estimation analysis

5.1.: Effects of Ecological Zone and Female-Headed Households on Nutritional Quality

Our results corroborate with the World Food Program's report which says that the Upper East, Northern and Upper West regions have the highest number of households that are either severely or

moderately food insecure [46]. From our results, we find that ecological location of the household is a significant determinant in adopting fish farming and the probability increase as one moves inland. The fisheries sector in Ghana is 40 percent women [47] and female-headed households are reported to be food insecure [24, 37].

Table 8. Food Consumption scores by Region.

Region	Min (FCS)	Max (FCS)
Western	32.00	84.50
Central	39.00	88.00
Greater Accra	60.00	88.00
Volta	31.50	89.50
Eastern	34.50	85.00
Ashanti	25.00	112.02
Brong Ahafo	17.30	109.00
Northern	33.00	71.00
Upper East	30.50	73.50
Upper West	27.00	73.50

Based on our findings, we conducted a post-estimation analysis in order to inform policy geared towards improving household food and nutritional security status. We use the FCS thresholds: poor (0 - 21), borderline (21.5 - 35) and acceptable (> 35) as a dependent variable and calculate the probabilities of households belonging to any of these categories. Most of the sample were in the rural area, so we are interested in the best way to help rural households improve their food security status in a cost-effective way. The variables of interest we analysed were being a fish farmer, a household with an educated female head and living in the rural savannah ecological zone. The interest in the savannah ecological zone is because the three Northern regions (Upper East, Upper West and Northern) have the highest prevalence of food insecurity (Table 8). In addition, from our analysis, we observed that moving away from the coast towards inland (forest and savannah ecological zones) increases the probability of adoption of fish farming.

The post estimation results show that a household in the rural savannah ecological zone with a female household head engaged in fish farming, has a higher probability of being food secure (96 percent) as shown in Table 9.

Table 9. Probability of improving food security in the rural savannah zone if household head is a female fish farmer.

Variable	Predicted prob.
poor	0.001* (0.00)
borderline	0.036* (0.01)
acceptable	0.963*** (0.01)
Observations	4,000

Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$ NOTE: ALL other regressors at their mean value except for FFHH = 1, Peri-urban = 0, SexHH= 0 (female) and ecology = 3 (savannah zone).

5.2. Policy Recommendations

The first policy suggestion from our findings is the promotion of fish farming in the three Northern regions, preferably aquaculture in water reservoirs using cages. The Northern regions are the least developed in the country and the cage fish farming requires low capital cost and it requires very little labour and less maintenance compared to the land-based fish farms, making cage culture better suited for low-income households [39]. The existing irrigation schemes in the North and Upper East regions (Bontanga, Golinga, Ligba, Vea and Tono) for rice and vegetable production will be good sources of water for the cage fish farms.

The second policy suggestion is to encourage women to engage in more than the processing of fish and getting involved in production as well. Our post estimation has positive implications for increasing household nutritional quality with women as head of household. As the source of income in the household is diversified, the probability of being food insecure reduces. Homemakers can support their husbands and contribute to the household income by adopting fish farming in a small scale on a piece of land at home or close to the home.

Finally, a study that uses a repeated cross section approach to assess the impact fish farming on household nutritional quality over a period is suggested.

6.: Conclusion

The study contributes to the literature by evaluating the impact of participating in fish farming on the nutritional quality of households in Ghana. We evaluated both direct impact pathways (consumption of fish) and indirect impact pathways (sale of fish to buy other foods) in this study using the Food Consumption Score (FCS) as proxy measure for food security.

On the margin, the probability of adopting fish farming increased with wealth, ecological zone, being a resident in a peri-urban area and household size while it declined with per capita household income. The average treatment effect of adopting fish farming on the food security of fish farming households showed an increase of 15.5 points. This translates into consuming fish twice in a week, roots/tuber or cereals once a week, pulses and legumes once a week, fats and oils or sugar and sugar products once a week and vegetables or fruits twice a week. We infer that fish farming increases the diversity and frequency of food consumed through direct consumption and not so much through the income effect.

Most importantly, our analysis showed that households in the savannah zone have an opportunity to engage in fish farming; especially those in the rural areas have a higher probability of improving their food security status. The provision of institutional, financial and technical support such as access to land, water resources, extension services and market services particularly for low-income households and women to engage in fish farming would help to improve food security. This would be especially true in Northern Ghana where poverty and malnutrition levels are highest. We recommend cage culture in Northern Ghana because it requires less upfront costs, labour and maintenance.

Acknowledgements: This project was supported by the Feed the Future Innovation Lab for Collaborative Research on Aquaculture & Fisheries through the United States Agency for International Development (USAID); Cooperative Agreement and by contributions from participating institutions. The Faculty of Renewable Natural Resources, Kwame Nkrumah University of Science, provided logistics and Technology (KNUST), a partner institution, students and professors from the Faculty of Food Science, KNUST in Ghana.

Availability of Data: Raw data were generated at Ghana Statistical Services. Derived data supporting the findings of this study are available from the corresponding author [ASA] on request.

Authors Contributions: All authors contributed equally to this paper.

Funding Details: This research was supported by funding from the United States Agency for International Development (USAID); Cooperative Agreement No. *EPP-A-00-06-00012-00* and by contributions from participating institutions.

Conflicts of Interest: The authors confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

References

1. Kavarazuka, N. "The Contribution of Fish Intake Aquaculture, and Small-Scale Fisheries to Improving Food and Nutrition Security: A Literature Review." Working Paper. 2010.
2. Skonhoft, A. and Gobena, A. "Fisheries and the Right to Food. Implementing the Right Food in National Fisheries Legislation." Food and Agriculture Organization (FAO) of the United Nations, Rome. 2009.
3. Rurangwa, E., Agyakwah, S.K., Boon, H. and Bolman, B.C. "Development of Aquaculture in Ghana. Analysis of Fish Value Chain and Potential Business Cases." Wageningen University and Research Centre. The Netherlands. 2015.
4. African States Bordering the Atlantic Ocean (ATFALCO). "Fishery and Aquaculture Development in Ghana." Series Report No. 1 of the Review of the Fishery and Aquaculture Industry in the 22 ATFALCO Member States. October 2012.
5. Ghana Fisheries and Aquaculture Development Plan (GFASDP). "Republic of Ghana Fisheries and Aquaculture Development Sector Development Plan." 2011.
6. Odei, D.K. "Sustainable Development of Aquaculture on the Volta Lake – A Case Study of the Asuogyaman District in the Eastern Region of Ghana." A Master Thesis in International Fisheries Management. UiT The Arctic University of Norway. 2015.
7. Ministry of Fisheries and Aquaculture Development (MOFAD). "Fish Production Percentage Contribution by Sector. 2016. Available online: www.mofad.gov.gh
8. Ministry of Fisheries and Aquaculture Development (MOFAD). "2012 Annual Report". Accra, Ghana: Ministry of Fisheries and Aquaculture Development. 2012. Available online: www.mofad.gov.gh
9. Nyanteng, V.K., and S. Asuming-Brempong. "The Role of Agriculture in Food Security in Ghana." Paper prepared for the Roles of Agriculture International Conference, Rome. FAO-ESA. 2003.
10. Afro-Asian Rural Development Organization (AARDO). "Food Security –Global Trends and Perspective. Report of the 32nd RECA Seminar, Japan 12925 July 2010.
11. Vigani, M. and E. Magrini. "Technology Adoption and the Multiple Dimensions of Food Security: The Case of Maize in Tanzania." *Selected Paper for EAAE Congress*, Slovenia. 2014.
12. Bezu, S., Kassie, G.T., Shiferaw, B. and Ricker-Gilbert, J. "Impact of Improved Maize Adoption on Welfare of Farm Households in Malawi: A Panel Data Analysis. *World Development*, 59: 120-131. 2014. Available online: <https://doi.org/10.1016/j.worlddev.2014.01.023>
13. Amare, M., S. Asfaw and B. Shiferaw. Welfare Impacts of Maize -Pigeon Pea Intensification in Tanzania. *Agricultural Economics*, Vol 43, No 1, pp.1–17. 2012.
14. Maxwell, D., J. Coates and B. Vaitla. "How Do Different Indicators of Household Food Security Compare? Empirical Evidence from Tigray." Feinstein International Center. Tufts University, Somerville, Massachusetts. 2013.
15. Abdulai A. & D. Aubert. A Cross-Section of Household Demand for Food and Nutrients in Tanzania. *Agricultural Economics* 31, 67-79. 2004. Available online: <https://doi.org/10.1016/j.agecon.2003.03.001>.
16. Thilsted, S.H., James, D., Toppe, J., Subasinghe, R. and Karunasagar, I. "Maximizing the Contribution of Fish to Human Nutrition." ICN2 Second International Conference on Nutrition. Rome, Italy. 2014.
17. Aiga, H., Matsuoka, S., Kuroiwa, C. and Yamamoto, S. "Malnutrition among Children in Rural Malawian Fish-Farming Households." *Transactions of the Royal Society of Tropical Medicine and Hygiene* 103, 827-833. 2009. Available online: <https://doi.org/10.1016/j.trstmh.2009.03.028>
18. Saaka M. and Osman, S.M. "Does Household Food Insecurity Affect the Nutritional Status of Preschool Children Aged 6-36 Months?" University of Development Studies, Tamale, Ghana. 2013.
19. Kassam, L. "Aquaculture and Food Security, Poverty Alleviation and Nutrition in Ghana: Case Study Prepared for the Aquaculture for Food Security, Poverty Alleviation and Nutrition Project." WorldFish Centre. Penang, Malaysia. 2014.
20. Rosenbaum, P. and Rubin, D. 1983. "The Central Role of the Propensity Score in Observational Studies for Causal Effects." *Biometrika*, Vol.70, No.1:41-55.
21. Ravallion, M. "Evaluating Anti-Poverty Programs." In Handbook for Development Economics, Vol, 4 ed. T. Paul Schultz and John A. Strauss: 3787-3846. Amsterdam: North-Holland. 2007. Available online: <https://cepr.org/sites/default/files/Evaluating%20antipoverty%20programs%20HDE4.pdf>
22. Gitonga, Z.M., De Groote, H., Kassie, M. and Tefera, T. "Impact of Metal Silos on Households' Maize Storage, Storage Losses and Food Security: An Application of a Propensity Score Matching." *Food Policy* Vol 43, pp.44-55. 2013. Available online: <https://doi.org/10.1016/j.foodpol.2013.08.005>

23. Garoma, D., Admassie, A., Ayele, G. and Beyene, F. "Analysis of the Significance of Fishing on Food Security Status of Rural Households around Lake Ziway and Langano in Ethiopia." *Journal of Economics and Sustainable Development* Vol. 4, No. 18. 2013. Available online: <https://iiste.org/Journals/index.php/IJEDS/article/download/8831/8979>
24. Kassie, M., Shiferaw, B. and Muricho, G. "Adoption and Impact of Improved Groundnut Varieties on Rural Poverty. Evidence from Rural Uganda." *Environment for Development Discussion Paper series*, Efd DP 10-11. 2010. Available online: <https://ideas.repec.org/p/rff/dpaper/dp-10-11-efd.html>
25. Rosenbaum, P. R. "Sensitivity Analysis in Observational Studies." *Encyclopedia of Statistics in Behavioral Science*, Vol 4, pp.1809-1814. 2005. Available online: <http://www-stat.wharton.upenn.edu/~rosenbap/BehStatSen.pdf>
26. Ghana Statistical Services (GSS). "Ghana Living Standards Survey 2012-2013 (GLSS 6). 2014. Available online: <http://www2.statsghana.gov.gh/nada/index.php/catalog/72/datacollection>
27. World Food Programme (WFP). "Food Consumption Analysis: Calculation and Use of the Food Consumption Score in Food Security Analysis." World Food Programme, Vulnerability Analysis and Mapping Branch. 2008.
28. Omiti, J.H., Otieno, D.J., Nyanamba, T.O. and McCullough, E. "Factors influencing the Intensity of Market Participation by Smallholder Farmers: A Case Study of Rural and Peri-Urban Areas of Kenya." *Afjare* Vol. 3, No. 1. 2009. Available online: <https://ideas.repec.org/a/ags/afjare/56958.html>
29. Frimpong, S., and S. Asuming-Brempong. "Comparative Study of Determinants of Food Security in Rural and Urban Households of Ashanti Region, Ghana." *International Journal of Economics and Management Sciences*, Vol. 2, No. 10, pp. 29 -42. 2013. Available online: https://works.bepress.com/ska_frimpong/3/
30. Ghimire, R., Wen-chi, H. and Shrestha, R. B. "Factors Affecting Adoption of improved Rice Varieties among Rural Farm Households in Central Nepal." *Rice Science*, Vol 22 No.1, pp. 35-43. 2015. Available online: <https://www.sciencedirect.com/science/article/pii/S1672630815000074>
31. Mendola, M. "Agricultural Technology Adoption and Poverty Reduction: A Propensity Score Matching Analysis for Rural Bangladesh." *Food Policy* Vol 32, pp.372-393. 2007. Available online: <https://www.sciencedirect.com/science/article/pii/S0306919206000790>
32. Oparinde, L.O. and Daramola, A.G. 2014. "Determinants of Market Participation by Maize Farmers in Ondo State, Nigeria." *Journal of Economics and Sustainable Development* Vol. 5, No. 1.
33. Shaik, Z. H. "Dynamics of Peri-Urban Agricultural Development and Farmers' Adaptive Behavior in the Emerging Megacity of Hyderabad, India." April 2014
34. *Journal of Environmental Planning and Management* 57(4). Available online: 10.1080/09640568.2012.751018
35. Larochelle, C., and Alwang, J. 2014. "Impacts of Improved Bean Varieties on Food Security in Rwanda." Selected Paper for the Annual Economist Meeting Annual Meeting, Minneapolis. July 2014.
36. Awotide, B.A. "Poverty and Income Inequality among Fish Farming Households in Oyo State, Nigeria." *Agricultural Journal* Vol 7, No. 2, pp.111-121. 2012. Available online: <http://dx.doi.org/10.3923/aj.2012.111.121>
37. Food and Agriculture Organization (FAO). "Fishery and Aquaculture Country Profiles. The Republic of Ghana." 2015. Available online: www.fao.org/fishery/facp/GHA/en.
38. Becerril, J. and Awudu, A. "The Impact of Improved Maize Varieties on Poverty in Mexico: A Propensity Score Matching Approach." *World Development* Vol. 38, No. 7, pp. 1024-1035. 2009. Available online: <https://doi.org/10.1016/j.worlddev.2009.11.017>
39. Jensen, L.P., Picozzi, K., Monteiro de Almeida, O. C., Jesus da Costa, M., Spyckerelle, L. and Erskine, W. "Social Relationships Impact Adoption of Agricultural Technologies: The Case of Food Crop Varieties in Timor-Leste." *Food Security* 6:97-409. 2014. Available online: <https://doi.org/10.1007/s12571-014-0345-5>
40. Ministry of Food and Agriculture (MOFA). "Pen and Cage Culture in Ghana." Not dated. Available online: www.mofa.gov.gh/site/page_id=10267
41. Mignouna, B., Manyong, M., Rusike, J., Mutabazi, S., and Senkondo, M. "Determinants of Adopting Imazapyr-Resistant Maize Technology and its Impact on Household Income in Western Kenya." *AgBioforum*, Vol 14, No. 3, pp.158-163. 2011. Available online: <http://www.academicjournals.org/IDAE>
42. Bamire, A.S., Fabiyi, Y.L. and Manyong, V.M. "Adoption Pattern of Fertilizer Technology among Farmers in the Ecological Zones of South Western Nigeria: a Tobit Analysis. *Australian Journal of Agricultural Research* Vol 53, pp.901-910. 2002. Available online: 10.1071/AR01095

43. Adeoti, A.I. "Factors Influencing Irrigation Technology Adoption and its Impact on Household Poverty in Ghana." *Journal of Agriculture and Rural Development in the Tropics and Subtropics* Vol. 109, No. 1. 2009. Available online: <http://jarts.info/index.php/jarts/article/view/73>
44. Headey, D., Chiu, A. and Kadiyala, S. "Agriculture's Role in the Indian Enigma: Help or Hindrance to the Undernutrition Crisis?" *Discussion Paper* 01085. Washington D.C.: International Food Policy Research Institute. 2011.
45. Masset E, Haddad L, Cornelius A, Isaza-Castro J. "A Systematic Review of Agricultural Interventions that Aim to Improve Nutritional Status of Children." London: EPPI-Centre, Social Science Research Unit, Institute of Education. University of London. 2011.
46. United States Agency for international Development (USAID). "Agriculture-to-Nutrition Pathways." Background Document for the Agriculture and Nutrition Global Learning and Exchange Event, Bangkok, March 19-23, 2013.
47. World Food Programme (WFP). "Comprehensive Food Security and Vulnerability Analysis, Ghana." Report. 2012. Available online: https://documents.wfp.org/stellent/groups/public/documents/ena/wfp257009.pdf?_ga=2.224866458.1854522484.1553532672-1541517651.1553532672
48. The High-Level Panel of Experts on Food Security and Nutrition (HLPE). "Sustainable Fisheries and Aquaculture for Food Security and Nutrition." A Report by HLPE. 2014. Available online: <http://www.fao.org/3/a-i3844e.pdf>