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Impact of Informal Networks among Cage Fish Farmers on Catch Potential

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ABSTRACT

Access to agricultural information is a critical factor, particularly among smallholder farmers in Sub-Saharan Africa. Many smallholder farmers in this region struggle on their own to access formal extension services, which limits their production potential. To circumvent this, many smallholder farmers are relying on information they share with their peers. To evaluate the impact of these information sources used by smallholder cage farmers the study employed a propensity score matching technique to compare farmers' groups relying on informal and formal sources. A comprehensive survey involved the selection of 384 respondents from thirteen distinct districts located near Lake Victoria in Uganda. The findings revealed that smallholder are cage fish farmers who rely on informal sources of information were sharing timely and relevant agricultural information with their peers about cage fish technologies. Additionally, the result from the estimated average treatment effect (ATT) revealed a difference of 4539.21622 Kilograms of fish annually over the control group and was statistically significant at t=2.32; p=0.006. In terms of fish harvested in kilograms annually for the treated group was 24627.7162, compared to 20088.5 for the untreated. Therefore, recognizing and integrating social networks into the existing policy interventions, can help in empowering smallholder farmers and facilitate sustainable agricultural development in Uganda's agricultural sector.

Keywords: Cage fish farming, catch potential, information sources, matching, propensity score, Uganda.

RÉSUMÉ

L'accès à l'information agricole est un facteur critique, en particulier parmi les petits agriculteurs en Afrique subsaharienne. De nombreux petits agriculteurs de cette région ont du mal à accéder aux services d'extension formels, ce qui limite leur potentiel de production. Pour contourner cela, de nombreux petits agriculteurs s'appuient sur les informations qu'ils partagent avec leurs pairs. Pour évaluer l'impact de ces sources d'information qu'utilisent les petits éleveurs de poissons en cage, l'étude a utilisé une technique de score de propension pour comparer les groupes de fermiers qui s'appuient sur des sources informelles et formelles. Une enquête exhaustive a impliqué la sélection de 384 répondants provenant de treize districts distincts situés près du lac Victoria en Ouganda. Les résultats ont révélé que les petits éleveurs de poissons en cage qui s'appuient sur des sources d'information informelles partageaient des informations agricoles opportunes et pertinentes avec leurs pairs sur les technologies de l'élevage en cage. De plus, le résultat de l'effet moyen estimé du traitement (ATT) a révélé une différence de 4539,21622 kilogrammes de poisson par an par rapport au groupe témoin et était

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statistiquement significatif à t=2,32; p=0,006. En termes de poisson récolté en kilogrammes annuellement pour le groupe traité, il était de 24627,7162, contre 20088,5 pour le groupe non traité. Par conséquent, la reconnaissance et l'intégration des réseaux sociaux dans les interventions politiques existantes peuvent aider à autonomiser les petits agriculteurs et faciliter le développement agricole durable dans le secteur agricole ougandais.

Mots-clés: Élevage de poissons en cage, Sources d'information, Potentiel de capture, correspondance, Score de propension, Ouganda.

Introduction

Uganda, situated in Sub-Saharan Africa, is a landlocked country with considerable aquaculture potential. It is prominently positioned as a leader in East Africa and ranks third across the continent (Of, 2020). However, cage culture is insignificant (Halwart *et al.,* 2007). Small-scale farmers who heavily rely on informal channels of information to improve their fish production primarily dominate the subsector. Access to information plays a crucial role in enabling farmers to sustain and enhance farm productivity. In the absence of government extension services, farmers use informal network sources to acquire agricultural information (Pratiwi and Suzuki, 2017).

Informal network platforms (Boahene *et al.,* 1999; Lyon, 2000) exist and have considerable aquaculture potential and provide interpersonal networks (Conley and Udry, 2010). In circumstances where formal institutions like government extension services are limited, informal networks play a crucial role. It is theorized that an individual's behaviour is influenced more by their relationships, technical connections, and network structures than by the norms they possess (Yang and Tang, 2003; Pratiwi and Suzuki, 2017). Informal networks play a crucial role in enabling the learning processes as actors actively construct knowledge bases (Mesele *et al.,* 2023) through sharing ideas and experiences.

Although informal network platforms play a crucial role in information sharing, their structures and ties differ (Bravo-ureta *et al.,* 2012). In their article, they highlighted a need to characterize the ties among the actors sharing a social network and the extent of accessing information and other resources. Some studies have partly explored how social structures affect knowledge sharing at the village level and the adoption of technologies to enhance production among farmers (Conley and Udry, 2010; Bell *et al.,* 2014; Ramani and Thutupalli, 2015; Aydin and Parker, 2018; Mania and Riley, 2019). Nevertheless, these studies mainly focused on adoption and little on access to information through social networks. Hoppe and Reinelt (2010) conducted an impact study on leadership development utilizing social network analysis. In their methodology, they used network structures and social graphic illustrations to explain the leadership styles in different sectors and organizations in the study area. In the same vein Taktak and Demir (2019) used spatial data to conduct a study on both public and private institutions. Their findings reveal that the network density, centrality, proximity and betweenness among the ego's network are calculated based on the number of alters. In a nutshell, these studies majorly focused on out-degree, in-degree, in-closeness, out-closeness and betweenness to examine and analyze social networks. They also highlighted a need for more spatial studies on determinants of network centralities using hierarchical clustering techniques.

ALTAŞ *et al.* (2012) applied social network analysis to investigate the impacts of staff positions within the telecommunication market. The study identified the important nodes in the social network, density, centrality, proximity, and betweenness based on the actors involved. In their conclusion, the characteristics of individuals are not important without understanding the determinants of loss of customers. Fisher (2016) built on the same study to understand the determinants of cooperation among workers in institutions. The findings reveal that successful cooperation increases as the size and structure of social networks expand, resulting in higher levels of job satisfaction.

Kahraman, (2008) study tested the gravity model with help of social network analysis. The research took into consideration international economics, centrality values, social network setups and co-membership values. The findings revealed that the majority of exporting nations were not connected to countries that were geographically proximate to them; however, the terms under direct and indirect relations play a crucial role. In their conclusion, they highlighted a need to evaluate the distance factor affecting foreign trade negatively in world trade. Despite the fact that the reviewed studies provide valuable insights into understanding the role of social networks in knowledge sharing, it is important to acknowledge that there is still a lack of clarity regarding their effects, among other factors. The dimensions of social network linkages in knowledge sharing or learning among actors, particularly regarding how informal social networks are formed through interpersonal processes, is still limited especially on how such relations shape catch potential among smallholder cage fish farmers in fishery-dependent communities. In this paper, we test whether informal sources of information can impact smallholder cage fish farmers' catch potential. Literature exploring the comparison of the effects of informal and formal sources of information among smallholder farmers is still limited. Thus, the study aims to address this gap in the literature by asserting that while both informal and formal sources of information are crucial factors in information gathering, they may have distinct effects in terms of the transmission of agricultural knowledge. Specifically, this study aims to make contributions to the existing literature in the following ways. Firstly, it describes the state of cage fishing farming system. Secondly, it apprehends the potential differences between smallholder cage fish farmers who use informal sources of information and those in comparison (users of formal information sources). Lastly, it hopes to enhance the limited existing literature on the impact of informal networks on the catch potential among the smallholder cage fish farmers. Therefore, this paper is organized into literature review, methodology, empirical results and a conclusion.

Methodology

Study area. The study was carried out around Lake Victoria, the largest natural water body in Africa and shared by Uganda, Kenya and Tanzania. Specifically, the study area covered 13 districts namely: Bugiri, Buikwe, Busia, Buvuma, Jinja, Kalangala, Kampala, Masaka, Mayuge, Mukono, Namayingo, Rakai and Wakiso (Figure 1). Geographically, Lake Victoria is located between a latitude of **-1.000000**, and a longitude is **33.000000**. And the portion of Lake Victoria in Uganda, is under coordinates of 1° 0' 0.0000" S and 33° 0' 0.0000" E.
(Google Map 2022). Victoria's surface is around 1,134 metres in terms of elevation above sea level and its greatest ascertained depth of 270 feet 82 metres. The lake has numerous islands, reefs and clear waters. Lake Victoria has more than 200 species of fish, of which Tilapia is the most financially significant. The lakes basin encompasses 92,240 square miles (238,900 square km). Lake Victoria's fishery resources contribute immensely to the socio-economic development of the East African Community. The fishery industry is one of the primary economic sectors realised from Lake Victoria, besides transport and hospitality.

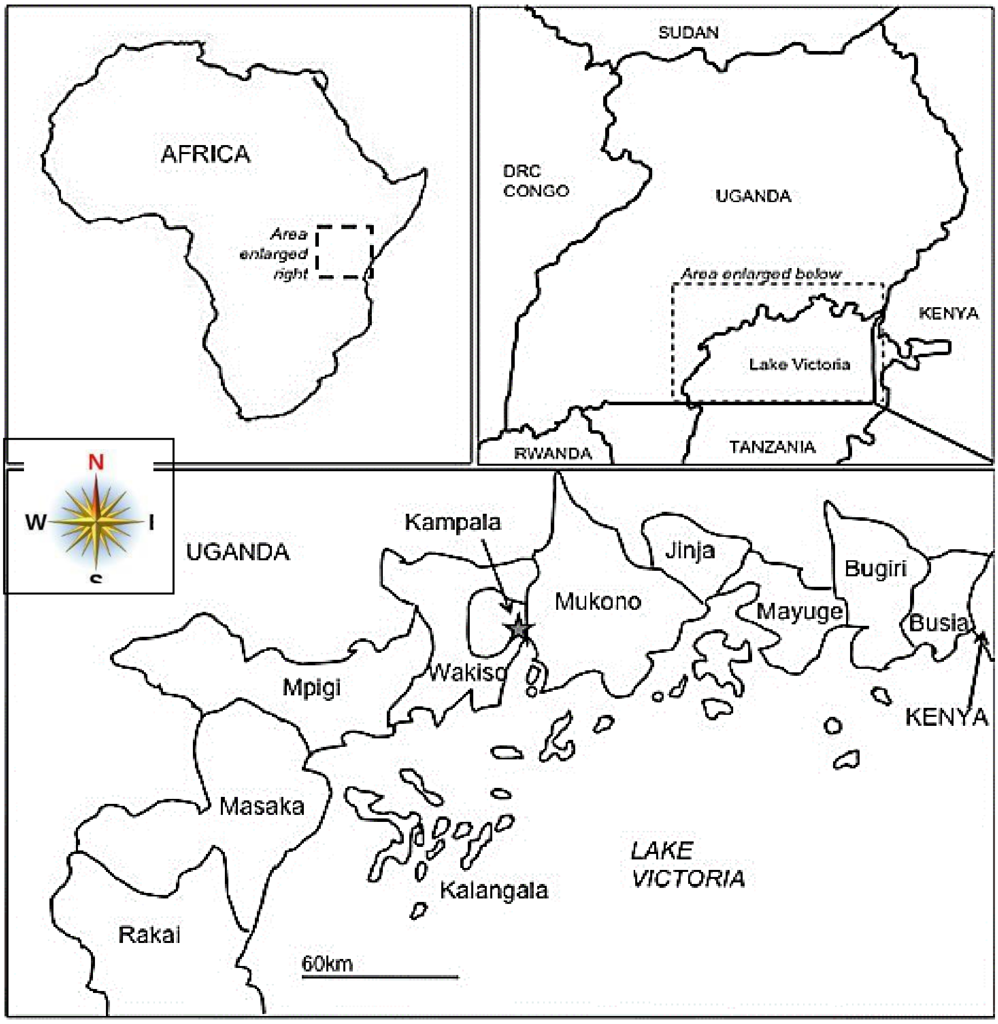

Figure 1. Map of the Study Area.

The fisheries industry contributes to GDP and acts as a major source of foreign exchange earned from fish exports. The sector also contributes directly and indirectly to the infrastructure and social development, such as roads, schools, and hospitals more so in remote fishing communities.

In the same vein, the Government of Uganda in its bid to embrace the Blue Economy (BE) has identified suitable sites for cage culture parks and ecosystem conservation strategies in Lake Victoria (World Bank, 2016; Balirwa, 2021). Through Uganda's Vision 2040 and in line with the East African Development Strategy, Lake Victoria has been recognized as a region of common economic interest (Anyah *et al.*, 2013). The lake offers ecosystem services like transport, water resources for both domestic and industrial water usage, as well as hydropower generation, fishing activities, ecotourism and food to over 40 million people (Applestein *et al.*, 2021). In addition, by end of 2021, approximately 1.5 million tonnes of fish were produced from Lake Victoria valued at 1.14 million USD (Applestein *et al.*, 2021), with an employment capacity of more than three million people dealing in fishery-related activities (Anyah *et al.*, 2013)

Table 1: Sample size and distribution.

S/N	District's name	Total smallholder cage fish farmers	Informal information users		Formal information users		Total sample size
			Total	Sample	Total	Sample	
1.	Bugiri	291	102	12	189	18	30
2.	Buikwe	319	119	12	200	20	32
3.	Busia	313	110	11	203	19	30
4.	Buvuma	284	104	10	180	18	28
5.	Jinja	308	109	13	199	20	33
6.	Kalangala	286	116	12	170	16	28
7.	Kampala	317	115	14	202	19	33
8.	Kyotera	244	104	10	140	15	25
9.	Masaka	249	119	12	130	13	25
10.	Mayuge	306	105	10	120	16	26
11.	Mukono	288	117	13	171	17	30
12.	Namayingo	310	109	13	201	19	32
13.	Wakiso	305	111	12	194	20	32
Overall total				**154**		**230**	**384**

Sampling Procedure. This study employed a multistage stratified random sampling approach. In the first stage, Lake Victoria and the 13 districts Bugiri, Buikwe, Busia, Buvuma, Jinja, Kalangala, Kampala, Kyotera, Masaka, Mayuge, Mukono, Namayingo and Wakiso were purposively selected because the Government of Uganda has been promoting cage culture for the past two decades. Lists of smallholder cage fish farmers were generated per district with the help of fisheries extension officers. Secondly, within the 13 districts, smallholder cage fish farmers were stratified into two groups: users who rely on informal sources of information and users who depend on formal sources of information.

The study conceptualised smallholder cage fish farmers who solely rely on their peers (social networks) as sources of information pertaining to cage culture to be "*informal information users*" and referred to as the treated group. Whereas the counterpart or the comparison group is made of farmers who depend on formal institutions like government and private extension services and are considered to be *"formal information users"* and referred to as the untreated group. In the end, a simple random sampling technique was employed to select the sample smallholder cage fish farmers who participated in this study.

A simplified formula presented by Edwards and Gaber (2014) was employed to determine the required sample size at a 95% confidence level, with a degree of variability = 0.5 and a level of precision = 5% (0.05).

$$\boldsymbol{n = \frac{Z^2pq}{d^2}} \quad \textbf{.................................. (1)}$$

where: n = the desired sample size; Z = Standard normal variable at the required level of confidence: p = the proportion in the target population estimated to have characteristic being measured: d = the level of tactical significance set; and $q = 1 - p$.

Methods of data collection. This study incorporated both qualitative and quantitative data sources. The secondary data were gathered through reviewing online resources and the information gathered was used to evaluate the current works in comparison with past studies. The primary data were collected using a two way–survey processes on the informal and the formal respondents. In the informal survey, interviews with key informants, focus group discussion and transect walks were performed with help of the community/beach management leaders. In addition, checklists were also developed for conducting key informant interviews and focus group discussions. A total of 13 focus group discussions and 13 key informant interviews were conducted. Then, structured questionnaires were administered to formal information users. The survey data from the formal information users were gathered using the prepared structured questionnaires conducted via face-to-face interviews. Prior to the survey, a pilot study was carried out to assess the data collection tool for clarity of the questions and to estimate the required time per respondent. For this purpose, 26 respondents, two per district were randomly selected for the pilot study. In addition, the survey tool was tailored to local conditions and finally, trained enumerators with good experience were engaged to administer the questionnaires for this study.

Analytical framework. This study employed both descriptive statistics and econometric models to analyse the data collected from the two primary sources. In addition, the assignment of the treated and control groups was based on the sources of information used by cage fish farmers within the study area. Both objective and subjective measures were employed to test the pre-selected parameters.

Statistical Analysis

Propensity Score Matching (PSM). This study applied *PSM* techniques to select, match and compare informal information users (social networks) and formal information users (government/hired extension services) with similar characteristics. The aim was to assess the impact of informal social networks on the smallholder fish farmer's catch potential. The treated group (*smallholder cage fish farmers who solely depend on their peers' social networks*) was matched with the untreated group *(smallholder cage fish farmers who depend on the government/hired extension services)*. Hence, observations regarding the estimated probability of being treated (propensity score), allowed not only for mean matching, but also for achieving balance in the distribution of observed characteristics between the two groups and the average differences in the outcome variables.

Estimation of PSM. In this study, the first concern was the choice of model to be employed to estimate the variables and the second was about which variables to be incorporated in the model. This study focused on two outcomes *(treated and untreated groups)*, hence a probit model was assumed best to carry out estimations since the dependent variable was a dummy variable (Caliendo *et al.,* 2005). Thus, the treated group took a value of one if the respondent is an informal information user (social network) and zero otherwise. The advantage of the probit model is that it transforms probability into coefficients and then takes the logarithm of the coefficients (Boateng and Abaye, 2019). In addition, it assigns a coefficient to each predictor, which assesses its independent contribution to variation in the dependent variable.

$$P_i = \frac{e^{Z_i}}{1+e^{Z_i}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textbf{(2)}$$

where; P_i = the probability of a respondent using informal information sources (social networks/treated group).

$$Z_i = Q_\theta + \sum Q_i X_i + \mu_i \ldots\ldots\ldots\ldots\ldots \textbf{(3)}$$

where; β_θ = intercept, β_i = regression coefficient to be estimated, X_i = variable and μ_i = Error term. The probability that a respondent belongs to untreated group or using formal information sources is

$$1 - P_i = \frac{1}{1 + e^{Z_i^F}} \text{ .... (4)}$$

and the odds ration expressed as

$$\frac{P_i}{1 - P_i} - \frac{1 + e^{Z_i}}{1 + e^{-Z_i}} = e^{Z_i} \text{ .... (5)}$$

Hence, to estimate the average impact of social network on the cage catch potential was expressed as

$$E[Y_1 - Y_0^1|D = 1] = E[Y_1|D = 1] - E|Y_0|D = 1] \text{ .... (6)}$$

where: Y is the harvest of fish in Kgs and D takes value of 1 for the treated group and a zero for the untreated group (control group). Hence, the outcome of our interest is the average difference in Y_1 *and* Y_0. Therefore, this study followed (Rosenbaum *et al.,* 2007) to calculate the average treatment effect on the treated (ATT) as follows:

$$ATT = E[Y_1 - Y_0|P(Z), D = 1] = E[Y_1|P, (Z), D = 1] - E[Y_0|P(Z), D = 0]. \dots \text{ (7)}$$

where: $P(Z)$ = Probability of selection conditional to Z or the propensity score (*pscore*), expressed as $P(Z) = P, (D = 1|Z)$.

In this study, the matching was done in two steps using Stata software version (15). The first step was to calculate the *(P-scores)* using Stata's *"pscore"* command. This first step was critical because of the need to estimate the balance of the observed distribution of covariates among the two groups. In the process, matching test was conducted to examine the differences in the covariates between the two groups. In the second stage, ATT was estimated using matching algorithms (*psmatch2*) specifically, considered the nearest neighbour (NN), kernel and radius matching methods. Hence, model specification for matching algorithm in this study was expressed as:

Step 1: Kernel matching

$$EY_i^{1-}.Y_i^0 = |p(X_i)T_i = 1) = \frac{1}{n^1}\sum_{t=(T_1=1)}^{n^F}[Y_i^1(X_i) - w_j(p(X_i))Y_j^0] \text{ .. (8)}$$

hence, the associated outcome (Y_i) of the treated unit i.

Step 2: Nearest neighbour model specification

In this study, the control group (*users of formal institutions as sources of information*) were denoted by C, was matched with the treated group (*users of informal social networks as sources of information*) denoted by C_i. Hence,

$$C(i) = min_j ||p_i - p_j|| \text{ .... (9)}$$

Step 3: Radius matching

In this study, each treated unit (i), was matched with respective control unit whose propensity score was under the predefined neighbourhood of the propensity score of the treated unit. Hence expressed as:

$$C(i) = \{p_j ||p_i - p_j|| < r\} \text{ .. .. (10)}$$

Conceptual framework for the study

In this study, it is believed that farmer's decision to use informal sources of information or otherwise, is influenced by a number of factors associated with demographic, socio-economic characteristics and the resource endowments (Namuyiga and Bashaasha, 2019; Wafula *et al.,* 2022).

Results and Discussion

Descriptive Statistics Results. In this study, a total of 16 explanatory factors were recognized and out of these, 8 were continuous and 8 categorical. Some demographics and socio-economic characteristics of the sampled population, with comparison of informal network users and formal network users are presented in (Tables 3 and 4) for continuous and categorical variables. Out of the 384 respondents, 65% were informal social network users, while the remaining 35%, were formal network user.

Table 2. Description, Measurement and expected sign.

Variable name	Measurement unit	Expected Sign
Dependent variable		
Fish Catch potential (Kgs)	1, if the farmer uses informal sources of information and 0, otherwise.	
Independent variables		
Age	Age of the cage farmer (in years)	+
Gender	0 for female and 1 for male	+/-
Experience in cage culture	in years	+
Education level	in years	+
Cage units	Number of cage units owned by farmer	+
Type of cage units used	2=HDE plastics; 1=Metallic; 3=Wooden	+/-
Location of cage units	1=200m into lake, 2=300-500m into lake, 3=600-1000m into lake and 4=beyond 1,000 metres	+/-
Target market	Type of market targeted	+/-
Group membership	Membership	+/-
Group size	Number of members in a group	+/-
No. of extension visits	1=Once a month, 2=Twice a month, 3=Once in a season	+/-
Distance to market	Distances of market in kilometer	
No. of trainings	Number of attended trainings on cage culture	

Table 3. Characteristics of continuous explanatory variables.

Types of Variables	Informal Networks Users (N=251)		Formal Network Users (N=133)		Combined		*t*-value	*p*-value
	Mean	Std.	Mean	Sd.	Mean	Std		
Age (*years*)	44.82	8.06	45.29	8.66	45.05	8.36	.5322	.2975
Farming experience (*years*)	3.74	1.16	3.53	1.19	3.64	1.18	-1.7636	.0475**
Education (*years)*	11.92	2.92	11.55	3.36	11.74	3.14	.1766	.4300
Cage units owned (*numbers*)	5.02	2.98	4.13	2.18	4.56	2.58	-3.0705	.0023***
Distance to market (*Kms*)	20.44	19.40	21.68	19.54	21.06	19.47	.5918	.2772
Knowledge scores	2.07	0.372	2.09	0.434	2.08	0.403	.4369	.3312
Attitudes scores	1.65	0.642	1.56	0.644	1.60	0.643	-1.2400	.2157
Perception scores	2.398	0.551	2.511	0.558	2.45	0.554	1.8984	.0584**

*The symbols: *, ** and *** denote statistical significance at 10%, 5% and 1% level, respectively.*

Table 4. Characteristics of categorical explanatory variables.

Variable	Categories	Informal Network users (N=251)		Formal Network users (133)		Total Value		Chi²	*p*-value
		Count	%	Count	%	Count	%		
Gender	Male	176	70.12	72	54.14	248	64.58	9.7106	0.002***
	Female	75	29.88	61	45.86	136	35.42		
Phone access	Yes	141	56.18	70	52.63	211	54.95		
	No	110	43.82	63	47.37	173	45.05	2.7097	0.100
TV access	Yes	138	54.98	113	45.02	251	65.36	0.3363	0.562
	No	69	51.88	64	48.12	133	34.63		
Group membership	Yes	167	67.53	84	33.47	251	65.36	5.0314	0.025**
	No	73	54.89	60	45.11	133	34.63		
Types of cages used	Metallic	197	90.98	121	78.49	318	82.81		
	HDE Plastics	21	0.75	1	8.37	22	5.73	12.2408	0.002***
	Wooden	33	0.27	11	13.15	44	11.46		
Location of cage farm	≥200m	85	35.07	33	24.81	116	30.21		
	200< and ≥500m	61	24.30	36	27.07	97	25.26	3.8627	0.277
	500< and ≥ 1000m	57	22.72	29	21.80	86	22.39		
	Above 1000m	50	19.93	35	26.32	85	22.14		
Target market	In community	31	12.35	20	15.04	51	13.28	6.7780	0.079*
	Nearby markets	143	56.97	87	65.41	230	59.89		
	Fish company	49	19.52	13	9.77	62	16.16		
	Direct export	28	11.16	13	9.77	41	10.67		
Religion	Muslim	12	4.78	20	15.04	32	8.33	13.4876	0.004**
	Christian	188	73.44	94	70.68	282	73.44		
	Pentecostal	45	17.93	18	13.53	63	16.41		
	Seventh day	6	2.39	1	0.75	7	1.82		

As indicated in the overall summaries of the descriptive results presented in Tables 3 and 4, a total of 8 variables were statistically significant. Thus, fish farming experience, number of cage units owned, perception of the respondents towards cage fish farming, gender, group memberships, types of cage units used, targeted fish market and religion show statistically significance at 1%, 5% and 10% respectively. In comparison of both informal and formal network users, as indicated in Tables 3 and 4, the mean age of informal network users is 44.82, and 45.05 for their counter parts. As regards experience in cage fish farming, informal network users have a mean value of 3.74, whereas their counter parts have 3.53. Thus, the mean difference was found to be statistically significant with p= 0.0475** value, this implies that there was significant difference on the mean farming experience in years of the respondents in the two groups at 0.5% level of significance. This implies that informal network users tend to be more experienced in cage fish farming than their counter parts.

On the other hand, number of cage units owned by the farmer is a decisive socio-economic variable in this sector. That is, it is vital for the quantity of fish produced and livelihood improvement. In comparison between the two groups under the study, informal network users have a mean value of 5.02, which is higher than their counter parts by 0.46. In addition, the mean difference between the two groups was found to be statistically significant with (*p = 0.0025)* value. The results are in line with Li *et al.* (2020) findings that exhibit a strong correlation between the size of social capital and farm output. Therefore, farmers with large social capital can easily acquire fish production skills and knowledge from their peers compared to their counterparts. This is in consideration of the few extension workers in the country, which stands at 1:1800 (Balirwa, 2021). Perception also plays a significant role in shaping decision-making (Ogundeji, 2022). In comparison with the two groups, informal network users had a mean perception scores of 2.398 and the corresponding figure for their counter parts was 2.511 (Table 3). In addition, the mean difference between the two groups was found to be statistically significant at (*p*=0.0584). This result was found to be in consistence with Ongachi *et al.* (2018) findings that showed a direct relationship between farmer's perception, knowledge sharing and approachability. Hence, informal network users are believed to interacting with their peers more often than their counter parts which enable them to perform better in cage fish farming. Among the categorical variables presented in Table 4, gender distribution of the respondents involved in the study, 64.58% were males and 35.42% were females. From the informal network users, which is the treated group 70.12% were males and 29.88% females. The formal network users (control group), 64.58% and 35.42% were male and female respectively. On an average, the chi-square test of gender distribution between the treated and control groups was found to be statistically significant (*p*=0.002). This indicates that there is a significant relationship between sex of informal network users and formal network users in use of cage fish farming technologies. This finding is in conformity with the results obtained by Abdi, (2014), which indicated that by virtue of difference in socio-economic values, a male person has a better chance to access different sources of information and participation in various social forums and programmes. On the other hand, for cage fish farmer's participation in social groups, the results show that among the treated group, 67.53% belonged to farmer's groups, whereas 54.89% were not. In the same vein, among the control group 65.36% participated in farmer's groups, and only 34.63% did not belong to any farmer's groups. This implies that farmers were eager to acquire knowledge through peer groups and social interactions. The chi-square test indicated value (*p*=0.025), implies that there was a significant variation between the group memberships and farmers' performance. This is in line with the study by Mkuna (2022), which revealed that group memberships facilitated information and knowledge exchange. As regards to the types of cage units, the results show that majority of the farmers in both groups used metallic cage units, followed by HDE Plastic units and wooden units were the least used. Under the treated group, 90.98% were found to be using metallic units, 0.75% HDE plastics cages and only 0.27% wooden cages. Whereas under the control group, 82.81% were used metallic units 5.73% HDE Plastic units and 11.46% wooden units. In comparison of the three types of cage units used within the study region, majority of the smallholder farmers used Metallic cages, followed by wooden units and HDE plastics were the least used.

This is attributed to the costs of investment in relation to material availability. The chi-square test indicated a (*p*=0.002), which implied a significant variation between the types of cage units used among the farmers and their performance. Hence, the findings are in conformity with the work of Okello *et al.* (2014), which indicated that choice and exploitation of agricultural technologies play a pivotal role in improving the productivity and income of smallholder farmers. On the side of farmers' targeted markets where they sell their fish, the results indicated four (4) types of market channels were mostly used. These included, within the local community, outside the local community, to fish processing company and direct export. Considering both groups (treated and control groups), most of the farmers included in the study sell the fish outside their respective communities (Villages/Beach Management Units). As regards to the treated group, 56.97% sell their fish in markets outside their villages, 19.52% sell direct to fish processing companies, 12.55% within their villages (localities) and only 11.16% do export their fish directly. Their counterparts (control group) involved in the study, 59.89% sell outside their villages, 16.16% to fish processing companies, 13.28% within their villages (localities) and only 10.67% do export fish directly. The chi-square test shown a significant variation of (*p*=0.079), which implies that participating in targeted markets is more important in explaining what influences the farmer's marketing decisions. This finding is in agreement with Mkuna, (2022), which revealed that socio-economic and production factors have varying effects on market participation. Regarding the respondent's religious affiliation in the study, among the informal network users (treated group), Muslim were 4.78%, Christians constituted 95.22%. On the other hand, among the formal network users (control group), 8.33% were Muslim, 91.67% were Christians. The variation between the two groups was statistically significant with (*p*=004). This implies that faith has influence on the technology adoption. The finding agrees with Atta-Aidoo *et al.* (2022), that individual's religion influences the attitude of the farmers.

Econometric Estimation Results. This section gives details on the econometric techniques applied in the study. The study focused at understanding the influence of informal networks among the smallholder cage fish farmers on catch potential in terms of quantity of fish produced/harvested. Secondly propensity score matching techniques were employed to compare smallholder farmers using informal social networks and their counter parts (treated and control groups). According to Rosenbaum *et al.* (2007), Propensity Score Matching (PSM), is applied to compare the treated and untreated groups based on similarities in all identifiable characteristics. Thus, computing the mean differences in outcomes across the two groups. In addition, the effect of validity among the treated and untreated groups relies on conditional independence and sizable common support across the treated and untreated groups (Shahidur *et al.,* 2010).

Empirical Findings

Preliminary tests. Prior to empirical analyses, both variance of inflation factor (VIF) and pair-wise correlation tests were conducted to ascertain the degree of multicollinearity for all the selected continuous and categorical variables as presented in Tables 5 and 6, respectively. Multicollinearity is a statistical situation where several independent variables employed in the regression model are correlated (Yang and Wu, 2016). Existence of multicollinearity leads to statistical insignificance of the explanatory variables, despite the overall model being significant. Thus, according to Hair (2011) the recommended threshold value for VIF test is less than 10, though the ideal should be less than 5. Based on the results presented in Table 5, multicollinearity was not a concern for this study, implying that all the tested explanatory variables were fit to be used in the regression model. The pair wise correlation test values presented in Table 6, ranged from 0.0026 to 0.1026, which are within the accepted range of 0.5. Hence, all the values exhibited weak relationships among the categorical variables. According to Sutton (2001) heteroscedasticity refers to a situation, where the residuals for a regression do not have constant variance. In this study, White test (Table 7) was applied in favour of Breusch–Pagan test, since the later only examines the linear form of heteroscedasticity. In addition, White test was capable of identifying more general forms of heteroscedasticity among the explanatory variables as recommended by Boyd (2020). However, the results revealed robust standard errors.

Results for Probit Regression. Therefore, the first stage of analysis, a probit model logit was used to estimate the propensity scores for matching purposes (Baker, 2000). Accordingly, explanatory variables were recognized and used to fulfil the conditions of matching the propensity. The next step after matching the propensity, the predicted odds values, from the binary estimation, matching was done using the matching set of rules (Admassie & Ayele, 2009). A matching algorithm was based on the collected data on both the treated and untreated groups. Hence, the regression results for the first step estimates in Table 8 demonstrate that there were number of explanatory variables, which were statistically significant at different levels.

Table 5. Variance Inflation Factor results for the continuous explanatory variables

Variable	VIF	1/VIF
Age of the respondent	1.11	0.902421
Years in formal education	1.11	0.902598
Distance to market	1.35	0.742293
Number of Cage units owned	1.21	0.823698
Years in cage fish farming	1.09	0.921548
Number of extension visits/month	1.10	0.918015
Knowledge score	1.23	0.876532
Attitude scores	1.14	0.859059
Perception score	1.16	0.838721
Mean VIF	**1.17**	

Table 6. Results for Pair wise correlation test

	Gender	Cage type	Target Market	Religion
Gender	1.0000			
Cage type	-0.0049	1.0000		
Target Market	-0.0632	0.0026	1.0000	
Religion	0.0195	0.1026	0.0249	1.0000

Table 7. White test results for heteroscedasticity

Source	**Ch^2**	**df**	**p-value**
Heteroscedasticity	138.870	116	0.0000
Skewness	179.010	17	0.0024
Kurtosis	0.220	2	0.1157
Total	318.100	135	0.0000
Chi2 (1)	0.14		
Prob>Chi2	0.0000		

Table 8. Propensity score estimation (Probit Regression outputs)

Treatment	Coef.	Std. Err.	z	P>|z|	95% Conf.	Interval
Knowledge scores	0.0460682	0.1983998	0.23	0.816	-0.3427882	0.4349246
Attitude scores	0.0925788	0.1190284	0.78	0.437	-0.1407125	0.3258701
Perception scores	-0.2708545	0.1377025	-1.97	**0.049**	-0.5407464	-0.0009626
Fish farming exp	0.1626528	0.0647517	2.51	**0.012**	0.0357417	0.2895638
Gender	0.5069434	0.1498578	3.38	**0.001**	0.2132258	0.8006611
Age of fish farmer	-0.0057365	0.0087945	-0.65	0.514	-0.0229735	0.0115005
Education level	-0.0238001	0.0241533	-0.99	0.324	-0.0711397	0.0235396
Extension visits	0.085787	0.0323611	2.65	**0.008**	-0.0223604	0.14921135
Social capital	0.0404633	0.0583483	0.69	0.488	-0.0738973	0.1548239
Phone access	-0.2213779	0.1504065	-1.47	0.141	-0.5161693	0.0734135
Tv access	0.1246094	0.1465552	0.85	0.395	-0.1626335	0.4118523
Fish cage units owned	0.0552927	0.0304655	1.81	**0.070**	-0.0044185	0.1150039
Fish farm location	-0.0017742	0.004173	-0.43	0.671	-0.009953	0.0064047
HDE Plastic Cage units	1.371091	0.5584315	2.46	**0.014**	0.2765857	2.465597
Wooden cage units	0.2720546	0.2540491	1.07	0.284	-0.2258726	0.7699818
Farm gate market	-0.6384051	0.2794033	-2.28	**0.022**	-1.186025	-0.0907847
Nearby market	-0.6526209	0.2230405	-2.93	**0.003**	-1.089772	-0.2154695
Direct Export market	-0.6027626	0.3124047	-1.93	**0.054**	-1.215065	0.0095394
Muslim faith	-0.7154599	0.257015	-2.78	**0.005**	-1.2192	-0.2117190
Pentecostal faith	0.672674	0.2032512	0.33	0.741	-0.3310977	0.4656325
Seventh day Adventist	0.4845096	0.6143059	0.79	0.430	-0.7195079	1.688527
_cons	0.2834721	0.837966	0.34	0.735	-1.358911	1.925855

No. of Obs = 384; LR chi^2 (21) =72.91; Prob > Chi^2 = 0.0000; Pseudo R^2 = 0.1471; Log likelihood = -211.28651.

Attitude scores were statistically non-significant. This is explained by the fact that educated individuals are anticipated to possess a greater amount of favourable attitudes toward agricultural skills, knowledge, and information in contrast to those who are uneducated (Khan *et al.*, 2007; Ding & Kinnucan, 2011). This contradicts the findings of the study by (Mburu & Wakhungu, 2007) indicated that education is recognized as a significant indicator of social transformation, as it enhances knowledge and skills that are valuable in gathering and interpreting information essential for making informed decisions. The farmers who possess the highest degree of centrality exhibit greater visibility within the network and play a crucial role in facilitating knowledge transfer and sharing of information (Durmuşoğlu, 2013; Faust & Fitzhugh, 2012; Wairimu *et al.*, 2022). The findings also support the notion of Mittal and Mehar (2016), who opined that farmers with lower levels of education tend to rely more on the social networks of fellow farmers, input dealers, and commission agents for support and information. The perception was negative and statistically significant at a 5% level on the usage of informal networks among cage fish farmers. The farming experience was positive and statistically significant at a 1% level on the usage of informal networks among cage fish farmers. This is attributed to the fact that farmers with many years in a group are more knowledgeable about fish farming. Farmers join groups for several reasons, including extension services, collective sales, and social reasons. This association appears to be influenced by their extensive experience and prolonged involvement in cage fish farming, which has heightened their visibility and recognition within the social network. As an actor's social network centrality increases, they gain greater access to information, resulting in competitive advantages (Pigatto *et al.*, 2020). Gender was positive and statistically significant at a 5% level on the usage of informal networks to access information among cage fish farmers since women and men may experience varying levels of access to information if their social networks differ on gender lines. Several attributes of social networks are anticipated to determine their degree of satisfaction for shaping awareness, and research has indicated that social networks frequently exhibit gender-based segregation, as described by Marimo *et al.* (2021) in seed technology adoption in Ghana and Magnan *et al.* (2015) in land resource use in India. In situations where social networks exhibit high levels of gender segregation, existing gaps in men's and women's access to information are likely to be strengthened (Fletschner, 2011). Extension visits were positive and statistically significant at a 1% level on the usage of informal networks to access production information. This could be attributed to the fact that farmers with numerous extension contacts are likely to be more knowledgeable about multiple market outlets that offer better prices for their products. Comparable findings obtained by Wosene *et al.* (2018), established that extension service increases farmers likelihood of acquiring important market information that will enable pepper producers to improve production methods, thus leading to more output. Age is statistically insignificant, and this is contradictory to the findings of Jenkins *et al.* (2011), who argues that as farmers grow older, they become less inclined to invest time and/or money in searching for information from multiple sources. Aged farmers may be less interested in modern formation from various sources because of low chances of getting their returns on investments in the short run (Mittal & Mehar, 2016). Young farmers are keener to acquire knowledge and information compared to older farmers. Farmers age is also correlated with farming experience (Jenkins *et al.*, 2011), and experienced farmers may depend on information gained through their own experience. Social capital was positive but statistically insignificant in the use of informal networks for accessing information among cage fish farmers. This is explained by the fact that social capital ties can also have drawbacks, as recognized in various studies on negative social capital or dark social capital (Gargiulo, 1999; Portes, 2020; Villalonga-Olives & Kawachi, 2017). Additionally, Portes (2020) noted that the negative effects such as the exclusion of outsiders, excess claims on group members, restrictions on individual freedom, and downward levelling norms. Within the context of this study, scholars have identified limitations in the dissemination of knowledge associated with the negative side of social capital, for example as Claridge. (2018), noted that *"dense and rich social relations can have a problematic dimension for collective initiatives*" and this includes the impact they may have on knowledge flows. This could hinder the acquisition of new knowledge derived from other forms of social capital (Eklinder-Frick *et al.,* 2011; Smith *et al.,* 2012). Furthermore, when networks are primarily composed of bonding social capital, isolated from knowledge brokers (such as advisors and extension staff), this could result in a reduced ability to implement changes on the farm and cultivate an environment that fosters innovation (Eklinder-Frick *et al.,* 2011; Smith *et al.,* 2012; Fisher, 2013). Farmers often mention other farmers as their most important information source (Smith *et al.,* 2012). Phone access was negative and statistically insignificant in the usage of informal networks among cage fish farmers. This is contrary to the study finding by Mania and Riley (2019), who found that farmers who have limited exposure to diverse ICTs training, including mobile phones, are more inclined to decrease their utilization of mobile devices for sharing information. This can be attributed to the fact that training exposure to any form of ICT is a vital factor in motivating and enhancing the level of technology adoption. The results also contrary with the study conducted by Syiem and Raj (2015) in India, which found that lack of training and practical experience in using mobile phone applications as well as the internet limited farmers from using them in sharing agricultural information from time to time.

The results showed that TV access was insignificant but positively associated with the extent of television use in information sharing. This is in contradiction with studies by Benard *et al.* (2020) that found as the level of illiteracy of farmers increases, their inclination to use television as a means of sharing information decreases. He attributed this to the fact that some of the televisions have menus that are sometimes complicated, and some operations instructions have been written in the English language, which is the problem and to illiterate farmers, becomes very difficult for them to use it at a certain level. Similar findings by Okello *et al.* (2014) indicate that a unit increase in a farmer's literacy level increases the degree of television use by a farmer. Information and communication technology enables connections to be established with geographically distant networks (i.e., internet, smartphones, and other communication mediums) (ICT), as shown in other studies such as Kunda *et al.* (2017) and Orcid and Orcid (2019).

ICT has facilitated the development of a networking culture amongst young farmers in particular (Milone & Ventura, 2019; Orcid & Orcid, 2019). Number of cage units owned and Cage type 2 (metallic cages) were positive and statistically significant at 10% and 5% levels, respectively, on the usage of informal networks among cage fish farmers. This can be attributed to the fact that farmers with the highest degree of centrality in a social network have greater visibility within the network and are essential in promoting knowledge transfer and information sharing (Faust & Fitzhugh, 2012; Durmuşoğlu, 2013; Scott & Stokman, 2015).

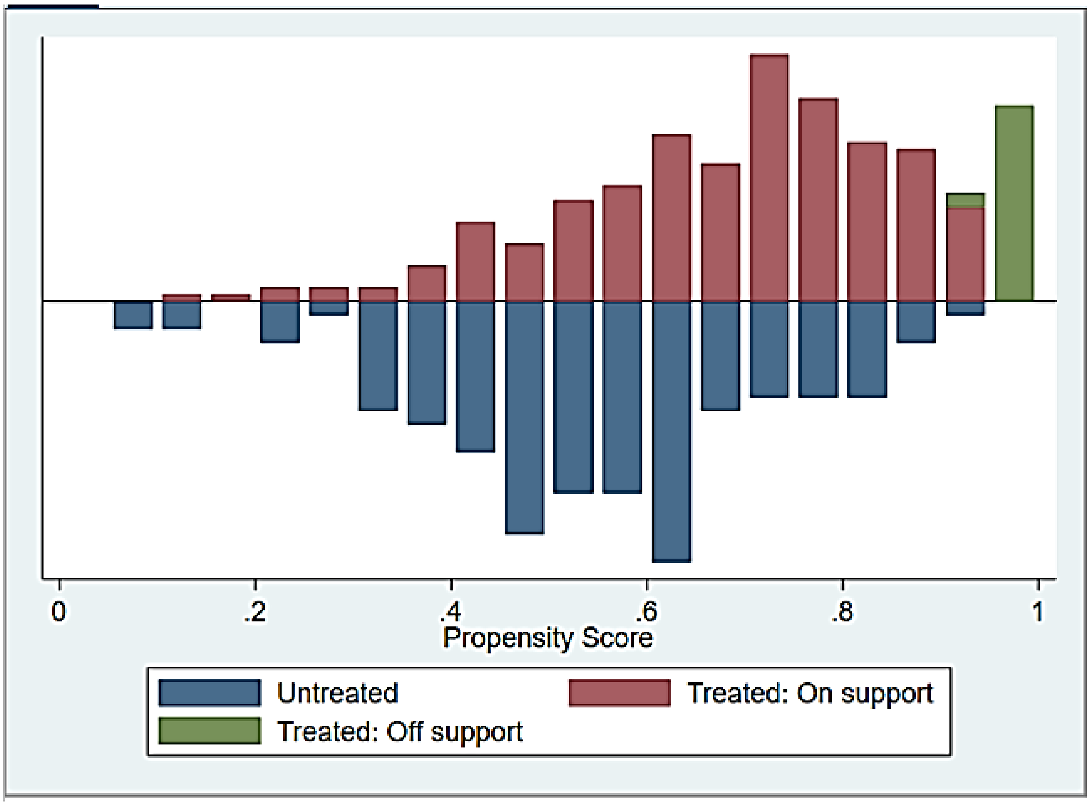

Figure 2. Propensity Score Histogram

Furthermore, these actors play a crucial role in coordinating the group. Their strong interpersonal relationships (friendship) contribute to their degree of centrality and prominence in the network. This result corroborates the observations of Adler (2002) and Borgatti *et al.* (2009). Individuals who value friendship as a significant form of social capital utilize it to establish and reinforce social relationships. The elevated degree of centrality exhibited by these three actors signifies the trust placed in them by other actors. According to Granovetter (2007), personal relationships and the networks stemming from them play a crucial role in cultivating trust, as rational actors base their decisions on the knowledge acquired through relationships forged with other actors.

Target markets 1,2,4 was positive and statistically significant at 5 %, 1%, and 10%, respectively, on the usage of informal networks among cage fish farmers (Pigatto *et al.*, 2020). The three individuals with the highest levels of competitiveness coincided with those who possessed the highest degree of centrality. Therefore, the competitiveness of fish farmers is influenced by internal and external factors, such as production volume, prices, market conditions, institutional factors, and the relationships established within their social network (Farina, 1999; Dyer & Singh, 2016).

Table 9. Post estimation of PSM

Sample	Pseudo R^2	Lr chi^2	P>chi^2	Mean bias	Med bias	Beta	R
Unmatched	0.412	218.46	0.000	62.7	58.0	214.6	28
Matched	0.002	52.60	0.864	4.2	3.6	24.0	0

Effect of informal sources of information on catch potential. A histogram was used to understand the propensity score distribution of the two groups based on the identical common characteristics. In addition, the histogram helped to check the presence of overlap or any common supporting conditions between the two groups (informal network users) and their counter parts (Pan *et al.*, 2012). Accordingly, the results in Figure 2 display the two regions of the informal network users (treated group) and formal network users (untreated group). The bottom half of the histogram showed the common support region for the treated group and ranges between 0.012 to 0.956. The y-axis showed the frequency of the propensity score distribution.

In consideration of the propensity scores and the overlaps displayed on the histogram, the untreated (formal network users) and the treated (informal network users) were within the specific region of the common support. Despite this, the few observations noticed as off support, which were rejected from the analysis, hence, it was concluded as a good match achieved for the study. Similarly, the post estimation results presented in Table 9, revealed that the value of the pseudo R^2 was very low (0.002) and insignificant *t*-test. Additionally, the values of pseudo R^2, indicated that the matching process achieved a well-balanced outcome between the treated and untreated groups. Thus, estimation of the average treatment effect on the treated (ATT) was conducted.

Estimating Treatment Effects (ATT)

In order to check for robustness of the results obtained from the regression model, different matching techniques such as Kernel based matching (KBM). Nearest neighbour matching (NNM) and radius matching (RM) were performed on the outcome variable namely the fish output in Kilogram as shown by the difference in ATT in Table 10.

In general, all the three matching techniques (KBM, NNM and RM) revealed an expressively higher output (fish produced annually) among the treated group compared to their counter parts with a statistically significant difference at *p*=0.001 level. The finding suggests that better fish production techniques were gained through proper exploitation of informal sources of information. In addition, the result also suggest that the selected matching algorithm was appropriate for the study.

Table 10. Performance criteria of matching algorithms

Outcome variable	Matched algorithms	Matched Samples		ATT (impact)	Std. Err.	*t*-test
		Treated	untreated			
Fish output (Kgs)	Kernel-based matching	251	133	2336.429	1404.193	1.664
	Nearest neighbour matching	251	133	189.325	2049.827	0.092
	Radius matching	251	133	2727.044	2804.037	0.973

Table 11. Estimation of ATT for fish output (Kgs/annum).

Variable	Sample	Treated	Controls	Difference	S.E.	T-stat
Output	Unmatched	24484.0717	21354.3008	3129.77096	1266.0051	2.47
	ATT	24627.7162	20088.5	4539.21622	1955.47693	2.32

Table 12. Estimation of regression adjustment for fish output (Kgs/annum).

	Fish output	Coef.	Robust Std. Err	z	p>|z|
ATET	Adoption Treated Vs Control	2384.31	1530.721	1.56	**0.004**
PO mean	Treated Control	1655.88	615.848	2.86	**0.000**

The impact of informal networks on the fish catches potential (output). As shown in Table 11, result from the estimated average treatment effect (ATT) revealed a difference of 4539.21622 kilograms of fish annually over the control group and this was statistically significant with (t=2.32; p=0.006). In terms of fish harvested in kilograms annually for treated group was (24627.7162) compared to (20088.5) for the untreated. The result suggests an overall increase fish production among the informal network users than their counter parts. This confirms that, informal network information sources are worth to be harnessed as a viable alternative in areas with limited access to formal extension services. In addition to PSM method applied to estimate the ATT on the fish catch potential, regression adjustment was performed. The estimated results of the average treatment effect on the treated (ATET), revealed that informal sources of information (informal networks) produced positive and statistically significant fish output differences between the treated and control groups as presented in Table 12. Hence, the study demonstrates that cage fish farmers who exclusively depend on informal networks to access information pertaining fish rearing, were better advantaged compared to their counterparts. In addition, the results from the ATET also substantiated that informal network users significantly produce more quantities of fish than the comparison group (Table 12).

Testing for hidden bias sensitivity analysis.

According to Ichino and Ichino (2006), the presentation of propensity-matching estimates should be accompanied by sensitivity analysis due to bias from unobservable characteristics. The assumption is that in case of a significant ATT, there might be overestimate on due to a hidden bias not failed to consider. Accordingly, the study employed the '*mhbounds*' procedure by Becker. (2000) and Caliendo *et al.* (2005) in Stata for sensitivity testing. This procedure utilizes the matching estimates to ascertain the confidence intervals of the outcome variables of different values of Γ (gamma). Gamma, odds of differential assignment due to unobserved factors; Q_mh+, Mantel–Haenszel statistic (assumption: overestimation of treatment effect); Q_mh−, Mantel–Haenszel statistic (assumption: underestimation of treatment effect); P_mh+, significance level (assumption: overestimation of treatment effect); P_mh−, significance level (assumption: underestimation of treatment effect).

Table 13. Sensitivity Analysis with Rosenbaum bounds.

Gamma	Q_mh+	Q_mh-	P_mh+	P_mh-
1	18.08	18.08	0	0
1.1	17.58	18.65	0	0
1.2	17.12	19.2	0	0
1.3	16.72	19.67	0	0
1.4	16.35	20.15	0	0
1.5	16.02	20.61	0	0
1.6	15.72	21.06	0	0
1.7	15.45	21.49	0	0
1.8	15.19	21.91	0	0
1.9	14.96	22.31	0	0
2	14.74	22.71	0	0

Table 13 provides the Mantel-Haenszel (mh) bounds result indicating, under the assumption of no hidden bias, the Q_mh test statistics are highly significant at 1% as indicated by their respective p-values (0). This indicates a highly significant treatment effect for informal social network interventions on the catch potential of the cage fish farmers. The Q_mh statistics indicate that the study is insensitive to the hidden bias at a 1% confidence interval. The closer the Q_mh to 1, the more sensitive the results are. Therefore, the observed results on the impact of informal social networks on the catch potential are insensitive to unobserved factors indicating that any unobserved factor did not influence the relationship between the treatment and outcome variables in the study.

Conclusions and Policy Implications

This study evaluated the causal effect of using informal sources of information among smallholder farmers in rearing fish in cages. Randomly, 384 respondents were selected from 13 districts sharing the waters of Lake Victoria in Uganda. The study employed PSM procedures to estimate the average treatment effect (ATE) and average treatment effect on treated (ATET) among the treated and control groups. The key findings revealed that the treated group (informal network users) accessed, and shared information on cage fish rearing. This enabled them to scale-up their production potentials significantly compared to their counter parts. More specifically, the PSM estimates revealed that the treated group produced more quantities of fish (kgs/annum) than the comparison group. This was demonstrated by significant results on all algorithms performed in this study.

This paper has important policy implications. First, enhancing the use of informal sources of information (informal networks) among smallholder farmers majorly in the fishery dependent communities could improve on fish productivity and their income. This could help the smallholder cage fish farmers to achieve optimum income and maximize margins for their livelihood. In addition, social ties enhance information flow, mostly related to fish rearing due to social interactions. This calls for a need to encourage more group formations among the smallholder farmers, where formal extension services seem to be limited. This entails guaranteeing support for the development of a more effective conventional methods for information sharing among smallholder fish producers. Hence, ensuring a model information sharing platform and a well organised policy content to integrate informal sources of information platforms used in cage fish rearing and efficient resource utilization. Lastly, there should be a paradigm shift from the tradition single formal extension service approach to the blended one which accommodates other social platforms that strengthen social ties and group formation initiatives among the smallholder farmers. Hence, smallholder cage fish farmers would increase on their fish productivity and income accordingly.

Note: Informal sources of information and informal social networks are interchangeably used in this paper.

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Statement of no-conflict of interest

The authors declare that they have no competing interests.

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