Farming under irrigation management transfer scheme and its impact on yield and net returns in Ghana

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A B S T R A C T

This article analyses smallholder irrigation management transfer (IMT) scheme participation and its impacts on yield and net farm returns of rice farmers in northern Ghana. We apply the endogenous switching regression and control function approaches to account for both observed and unobserved policy-relevant drivers of farmers' decision to participate in IMT and potential endogeneity. Our results show that farmers' participation in the IMT scheme can enhance their rice yields by 39.56 % and net farm returns by 24.52 % in Ghana. The increased in yield and net returns are linked to the perceived improvement in water supply and availability of water at critical stages of production as well as personal, farm, institutional and location characteristics. Farmers' decision to operate under IMT schemes are influenced by both observed and unobserved drivers. Large scale rice production tends to be viable under IMT schemes. We discuss the policy implications of IMT scheme participation and recommend succinct policies based on its impact on the welfare of smallholder farmers in developing countries.

1. Introduction

In Africa and other developing countries, several irrigation schemes and projects managed by government agencies struggled to attain the projected targets, particularly with regards to the operation and maintenance of the irrigation facilities (Food and Agricultural Organization of the United Nations [FAO], 2007; Kakuta, 2019; Sally and Abernethy, 2002). As a result of the management failures by governments, organizations such as the World Bank, FAO and International Water Management Institute (IWMI) promoted the idea of devolving government agencies from managing irrigation schemes and transfer the management responsibilities to private entities, usually water users associations (Hatcho and Tsutsui, 1998; Food and Agricultural Organization of the United Nations [FAO], 2007; Kakuta, 2019). The process of devolving irrigation management authority and responsibility from state agencies to private entities is referred to as irrigation management transfer (IMT). The private entities may consist of farmer organizations, water user associations (WUA), non-governmental agencies, or local government agencies (Fujiie et al., 2005; Giordano et al., 2006; Zhang et al., 2013). IMT has been used as an instrument for the reformation of irrigation

sector in over 60 countries, including Ghana (Food and Agricultural Organization of the United Nations [FAO], 2007; Kakuta, 2019).

The Water Development and Management Unit of FAO, agricultural water resource managers, researchers and policy makers having realized the importance of IMT, decided that there should be an evaluation and documentation of IMT across countries where IMT is implemented (Food and Agricultural Organization of the United Nations [FAO], 2007; Kakuta, 2019). The call for IMT evaluation should provide (i) in-depth understanding on IMT operations, approaches, success stories and challenges in different countries; and (ii) useful lessons and feedback will be provided to the existing countries and those who are in the process of introducing IMT policy (Food and Agricultural Organization of the United Nations [FAO], 2007; Kakuta, 2019). Therefore, several studies have been conducted on IMT schemes (Ghamire and Griffin, 2014; Olen et al., 2016; Senanayake et al., 2015; Wang et al., 2006; Wokker et al., 2014). Some studies have examined the mode of operation of the IMT scheme, i.e. whether the irrigation scheme is managed by individual farmers (Coward, 1980; Uphoff, 1986) or farmer-state partnership managed irrigation schemes (Sam-Amoah and Gowing, 2001).

Some earlier studies concentrated on the success or failure of the IMT

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schemes (Fujiie et al., 2005; Rap, 2006; Senanayake et al., 2015) in the Philippines. Wang et al. (2006) demonstrated that not only does the implementation of water management reforms matters, but the establishment of supporting institutions is crucial in China's irrigation systems. Ghamire and Griffin (2014) contended that when it comes to water right transfers, irrigation districts often tend to under-participate in agricultural-to-municipal water transfers relative to non-irrigation districts. Ghamire and Griffin (2014) further revealed that producers in irrigation agricultural systems tend to react and adapt to changes in water usage policies and climate variation. Wokker et al. (2014) examined irrigation water management in Cambodia and found that water usage fees has the potential to lead to water reallocation between sectors. In India, government has predominantly controlled irrigation management, distributional flows and irrigation development (Ratna-Reddy and Prudhvikar-Reddy, 2006). Rap (2006) argued that the success of IMT policy is not straight forward but largely depends on the cultural and ideological understanding or performance. Other extant empirical studies amplified the possible linkage between IMT schemes and the scale of production in India (van Koppen et al., 2003; Ratna-Reddy and Prudhvikar-Reddy, 2006). IMT is not a "time-bound" intervention; countries that have adopted IMT operate at their own pace and acclimatize to their physical, cultural, social and economic environments (Food and Agricultural Organization of the United Nations [FAO], 2007, 1999).

In Ghana, Braimah et al. (2014) assessed community-based participatory irrigation management schemes in Northern Ghana and found that Bontanga and Golinga irrigation schemes have received minimal participation by farmers. The missing information in most of the IMT policy studies is rigorous analyses of farmers' participation decisions in the IMT schemes. Namara et al. (2011) investigated the performance and barriers of emerging irrigation schemes in Ghana and found that inadequate research and extension service hinder the success of emerging irrigation systems. Kakuta (2019) identified lack of funds, institutional and technical support as barriers to successful operation of WUA at the Kpong Irrigation Scheme in Ghana. Puozaa (2015) examined the allocative efficiency of tomato production under IMT irrigation in the Upper East region of Ghana. Also, Dittoh et al. (2013) examined the emergence of vegetable farming under irrigation for income generation, job creation and food security. Food and Agricultural Organization of the United Nations [FAO] (2007) assessed the performance of irrigation schemes in Ghana and suggested that appropriate impact evaluation methods are required to evaluate the actual impact of IMT on farm income and yields.

In spite of the efforts made by researchers and IMT scheme managers to promote IMT polices, farmers' participation in the schemes has been low in Ghana (Braimah et al., 2014; Kakuta, 2019); signifying that the existing knowledge has some gaps. Firstly, the low participation in IMT suggests that current knowledge is not sufficient and that more empirical evidence is needed on the drivers of farmers' participation in IMT schemes. Secondly, little attention has been paid to identifying the magnitude and precise impact of contemporary IMT on welfare, food security, and nutrition of the rural poor. Furthermore, most of the existing studies focused on the management and governance of the IMT scheme, the financial and economic viability of government managed irrigation systems (Mukherji et al., 2009; Owusu, 2016; Sam-Amoah and Gowing, 2001; Shah et al., 2002), with little focus on the impact of the IMT policy on participating farmers, particularly in sub-Saharan Africa. Studies that have attempted to examine IMT scheme participation and its impact on participants is limited to economic efficiency under the IMT scheme (Puozaa, 2015; Sam-Amoah and Gowing, 2001; van Koppen et al., 2003; Zhang et al., 2013). Sakthivadivel et al. (2001) assessed how differences in farm sizes may affect water distribution, yield and net returns of smallholder farmers participating in the IMT scheme in Taiwan.

The objectives of the present paper are to: (i) determine the drivers of farmers' participation in the IMT scheme, (ii) determine whether

participating farmers operating under the IMT scheme perform better in terms of rice yields and net farm returns than non-participating farmers, and (iii) analyse how the scale of rice farms under the IMT scheme impacts on the welfare of the households. The main hypothesis tested in the present paper is that rice farmers who participate in the IMT scheme have higher yields and net farm returns than non-participants.

This study contributes to existing knowledge in the following ways. First, this study contributes to the strife for improvement and better understanding of irrigation sector reforms embarked by the World Bank, FAO, IWMI and national and international organizations. Second, we contribute to the scanty knowledge on the relevant factors that hinder or enhance farmers' decision to participate in the IMT scheme. Moreover, the paper accounts for both observed and unobserved drivers of participation in IMT scheme. In particular, this paper accounts for selection bias using the endogenous switching regression (ESR), and employs the control function approach suggested by Wooldridge (2015) to address the potential endogeneity of some policy-relevant variables. These approaches allow to unravel the impact of IMT policies to isolate the impacts or attribute the impacts directly to participation in the IMT. In the Ghanaian irrigation case studies, we contribute to the promotion and development of activities, participation and sustainability of IMT policy. Finally, this paper brings out the impact of IMT from a different perspective. Prevous studies have looked at the impact of IMT using before and after approach (Puozaa, 2015; Sam-Amoah and Gowing, 2001). This study looks at how farmers operating under IMT scheme are performing relative to those who are not participating in IMT.

2. Overview of IMT schemes in Ghana

The IMT policy started in the mid-1970s (Food and Agricultural Organization of the United Nations [FAO], 2007). However, the peak of its adoption and application took place in early 1990s when governments were struggling to maintain existing irrigation systems and infrastructure due to increasing financial problems as well as growing dissatisfaction with performance of irrigation systems (Food and Agricultural Organization of the United Nations [FAO], 2007; Namara et al., 2011). In Ghana, IMT started in the Volta River Basin in 1999. The transfer of operation and management happened at the river basin level. The operation and management were transferred to water users association operating on small-scale schemes with less than 100 ha (Food and Agricultural Organization of the United Nations [FAO], 2007). The government transferred only part of the operation and management authority to the water users associations. After the transfer to the water users associations, farmers within the reach of the irrigation schemes may decide to join the scheme or not. Participation is not compulsory; the decision to join or exit depends on the farmer and are influenced by several factors such as the water usage fees, the expected benefit, timeliness, and quality of water delivery and location of the land. Farmers under the scheme receive extension services and technical advice on improved farming practices and technology. The extension agents and NGOs (e.g. ACDEP, ADVANS, RAINS) provide financial training, field trips, local and international tours for farmers under the IMT scheme.

Ghana has about twenty two formal irrigation schemes covering about 8,611 ha in the various regions of the country (Namara et al., 2011). Food and Agricultural Organization of the United Nations [FAO] (2007) country report on pilot cases of IMT conducted in Ghana in early 2000 revealed that the introduction of IMT has increased the operation and management costs to government and farmers (Table 1). However, there has been an increase in efficiency of water usage fees collection.

The report revealed that the timely water delivery, equity of water delivery and water logging after the implementation of IMT had remained unchanged. It was also found that quality of maintenance, area irrigated, crop yields and farm income had decreased after IMT (Food and Agricultural Organization of the United Nations [FAO], 2007). The decrease in irrigated areas, yield and income was contrary to

Table 1
IMT outcomes and impacts in Ghana (Volta River Basin).

Indicators of outcome and impact	Observed impact
Operation & management costs to farmers	Increased
Operation & management costs to government	Increased
Efficiency of fee collection	Increased
Quality of maintenance	Decreased
Timeliness of water delivery	Remained about the same
Equity of water delivery	Remained about the same
Area irrigated	Decreased
Crop yields	Decreased
Farm income	Decreased
Water logging	Remained about the same

Source: Food and Agricultural Organization of the United Nations [FAO] (2007).

findings from most countries that adopted IMT policy. The reduction in irrigated areas, yield and income was attributed to the poor maintenance of the irrigation facilities and lack of technical capacities in water users associations (Food and Agricultural Organization of the United Nations [FAO], 2007). In recent years, the Ghana Shared Growth Development Agenda, (GSGDA, 2013), the Coordinated Programme of Economic and Social Development Policies (NDPC, 2017), and the flagship agricultural transformation program, have made significant improvements in the quality of maintenance and technical facilities. Hence, there is the need for further evaluation of IMT schemes.

3. Empirical specification and estimation strategy

To model the impact of IMT on yield and net farm returns we followed the endogenous switching regression (ESR) and control function approaches (Bourguignon et al., 2007; Lee, 1982; Wooldridge, 2015). These approaches allow us to account for selection bias and endogeneity associated with both observable and unobservable drivers (Lee, 1982). The ESR approach also avoids the limitations of propensity score matching (PSM) and difficulties with the Heckman two-stage estimation (Smith and Blundell, 1986; Smith and Todd, 2004). The PSM only accounts for selection bias due to observable characteristics (Rosenbaum and Rubin, 1983). The Heckman two-stage estimation could address the selection bias problem but it has restrictive assumption of normally distributed errors (Heckman, 1979). There are also difficulties in identifying instruments (Heckman, 1979; Smith and Blundell, 1986; Smith and Todd, 2004). If participation in the IMT policy by the rice farmers had been randomized, the issue of self-selection would not have arisen.

We assume that farmers participate in IMT to maximize their anticipated benefit. We denote the net benefit that farmer i derives from participating in the IMT scheme by I_P and the net benefit from non-participation in the IMT as I_{NP}. The rice farmer tends to participate in the IMT scheme if the expected net benefit from participation exceeds that of non-participation ($I_P > I_{NP}$). Representing the net benefit associated with the IMT scheme participation by a latent variable I_i^*, we can express the function of observable characteristics Z_i in the form:

$$I_i^* = \alpha Z_i + \mu_i; I_i = 1[I_i^* > 0] \tag{1}$$

where I_i is a binary dependent variable taking a value of 1 for farmers who participate in the IMT scheme, and 0 otherwise. α is a vector of parameters to be estimated and μ is the error term with zero mean and constant variance. Z is a vector of personal and household characteristics, plot and farm-level characteristics, institutional characteristics, farmers' perceptions on the IMT scheme, and location-specific dummies. The personal and household characteristics include farmer age, gender, education and household size. The plot-level characteristics include farm size, quantity of nitrogen fertilizer applied, quantity of weedicides applied, quantity of seeds used, labour input and improved seeds. The institutional characteristics include access to credit, access to extension services and participation in off-farm employment. The IMT perception variable includes IMT scheme benefit. The location dummy variables are

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Policy-relevant variables, notably, off-farm work participation and extension contacts are potential endogenous variables in the function postulated to explain farmers' participation in the IMT scheme (Donkor et al., 2016; Issahaku and Abdulai, 2020). Engagement in off-farm work is possibly endogenous since participation in some climate-smart technologies such as irrigation management requires intensive labour and individuals or households involved in off-farm activities may find it difficult to adopt such schemes (i.e. labour-loss effect) (Issahaku and Abdulai, 2020). Additionally, income obtained from off-farm work can be used to acquire farm inputs or invest the money in the adopted technology (income-effect) (Koundouri et al., 2006). In terms of extension contacts, it is likely that farmers who have joined the IMT scheme may draw more visits by extension agents than non-participants (van Rooyen et al., 2017; Wheeler et al., 2017). Thus, since participants are working under an organized scheme, it is easier for extension officers to liaise with through the management of the scheme and water user associations.

In the current paper, we account for the potential endogeneity using the the approach suggested by Rivers and Vuong (1988) and a control function approach suggested by Wooldridge (2015). In the first stage of this approach, the potential endogenous variable is specified as a function of all the other variables in the IMT scheme participation Eq. (1), together with a set of instruments as:

$$\Gamma_{ij} = \delta Z_{ij} + \phi S_{ij} + \varepsilon_{ij} \tag{2}$$

where Γ_{ij} is a vector of the probable endogenous variables, which include off-farm employment participation and extension contacts. Z_i is defined above, and S_{ij} is a vector of instruments that influence the endogenous variables, but not IMT scheme participation. Distance from farmer community to district capital market was used to instrument off-farm employment participation, whereas distance to the nearest district Ministry of Food and Agriculture (MoFA) office was used to instrument extension contacts (Issahaku and Abdulai, 2020). Distance to municipal capital market affects off-farm employment because petty trading was identified as the dominant off-farm activity in the study areas. Hence, farmer who are closer to the municipal capital market are more likely to engage in off-farm employment and vice versa. Distance to district nearest MoFA office will affect extension contact variable, for farmers closer to the office are likely to have easier access to and visits by extension agents who are stationed in the MoFA offices and vice versa. These variables directly influence off-farm employment and extension contact but not IMT scheme (Issahaku and Abdulai, 2020).

Due to the binary nature of the dependent variables, we specify the first stage Eq. (2) as a probit. In the second stage, we express the IMT scheme participation equation as a function of all the explanatory variables, including the residuals from the first stage regression as:

$$I_i^* = \beta Z_{ij} + \alpha_{ij}\Gamma_{ij} + \varphi_{ij}\widehat{R}_{ij} + \xi_i \tag{3}$$

where Γ_{ij} is a vector of the potential endogenous variables, Z_i vector retains its original definitions, $\widehat{R}_{ij}$ denotes the residual terms saved from the estimated function explaining the factors affecting off-farm employment participation and extension contacts, respectively. Including the residuals help to obtain estimates that are reliable and unbiased as well as robust Hausman-type test for exogeneity of possible endogenous variables (Wooldridge, 2015).

Farmers take into consideration the expected outcome, notably, productivity or net farm returns of their decision to participate in the IMT scheme. In the endogenous switching regression framework, the outcome equation is specified by categorizing the rice farmers into participants and non-participants as:

$$Q_{iP} = X_i'\omega_P + \lambda_{ijP}\Gamma_{ijP} + \varphi_{ijP}\widehat{R}_{ijP} + \upsilon_{iP} \text{ if } I_i = 1 \tag{4}$$

$$Q_{iNP} = X'_i \omega_{NP} + \lambda_{ijNP} \Gamma_{ijNP} + \varphi_{ijNP} \widehat{R}_{ijNP} + \upsilon_{iNP} \text{ if } I_i = 0 \qquad (5)$$

where Q_{iP} and Q_{iNP} are the outcome variables for IMT scheme participants and IMT scheme non-participants, respectively. Since Γ_{ijP} and Γ_{ijNP} are treated as potential endogenous variables, the parameters φ_{ijP} and φ_{ijNP} of the residual terms $\widehat{R}_{ijP}$ and $\widehat{R}_{ijNP}$ should not be significantly different from zero even at the 10 % level (Rivers and Vuong, 1988; Wooldridge, 2015).

For the purpose of proper identification, the variables farmers' perception of IMT scheme and chieftaincy were chosen as valid instruments based on previous literature (Braimah et al., 2014; Di Falco and Veronesi 2013; Issahaku and Abdulai, 2020). These variables have been found not to directly influence rice yields and net farm returns but are potential drivers of farmers' decision to participate in IMT scheme (Di Falco and Veronesi 2013; Issahaku and Abdulai, 2020). Farmers' perception has been found to impact directly on adoption of climate-smart agronomic practices but may not directly influence farm revenues (Di Falco and Veronesi 2013; Issahaku and Abdulai, 2020). Braimah et al. (2014) noted that in Northern Ghana, membership of local chieftaincy leadership has a direct influence on participation in local-level management structures and interventions, including the implementation of IMT, but does not directly influence yield and outcome of interventions. The validity of the selected instruments are tested using a falsification test. The falsification test ascertains if the instruments only affects the decision of farmers to participate in IMT scheme, but not yield and revenue (Di Falco and Veronesi 2013).

We estimate the participation Eq. (3) and the outcome Eqs. (4) and (5) together using the Full Information Maximum Likelihood (FIML) as suggested by Lokshin and Sajaia (2004) to avoid a heteroscedasticity problem. The parameter of interest when applying the ESR to analyse impact of an intervention is the average treatment effect on the treated (ATT_{ESR}) (Lokshin and Sajaia, 2004) specified as:

$$\begin{aligned} ATT_{ESR} &= E(Q_{iP}|I=1) - E(Q_{iNP}|I=1) \\ &= Z'_i(\omega_P - \omega_{NP}) + (\lambda_{ijP} - \lambda_{ijNP})\Gamma_{ij} + (\varphi_{ijP} - \varphi_{ijNP})\widehat{R}_{ij} + (\sigma_{\xi P} - \sigma_{\xi NP})\gamma_P \end{aligned} \qquad (6)$$

where $E(Q_{iP}|I=1)$ is the expected value of the outcome Q_{iP} for a farmer who participated in IMT; $E(Q_{iNP}|I=1)$ is the expected value of the same farmer had he or she decided not to participate in IMT; $\sigma_{\xi P} = Cov(\xi \upsilon_P)$ and $\sigma_{\xi NP} = Cov(\xi \upsilon_{NP})$ denote the covariance of the error terms; γ_P and γ_{NP} denote the selectivity terms (inverse mills ratios). Endogenous switching is observed when the correlation coefficient of ξ and $\upsilon_P (\rho_{iP} = \sigma_{\xi P}/\sigma_\xi \sigma_P)$ or ξ and $\upsilon_{NP} (\rho_{iNP} = \sigma_{\xi NP}/\sigma_\xi \sigma_{NP})$ is statistically significant, suggesting that selection on unobservable factors is present. The signs and significance of the correlation coefficients (ρ_{iP}, ρ_{iNP}) and the selectivity terms (γ_P, γ_{NP}) are very relevant. Notably, a negative selection bias occurs when $\rho > 0$, implying that farmers whose rice yields and net farm returns are below average have higher tendency to participate in the IMT scheme. Positive selection bias occurs if $\rho < 0$, indicating that farmers whose rice yields and net farm returns are above average have higher tendency to participate in the IMT scheme.

4. Data and descriptive characteristics

The data used in the present study comes from smallholder rice farm households in the Upper East and Northern regions of Ghana. Compared to other regions in Ghana, the selected regions are noted for rice production, have unimodal rainfall pattern, and are prone to erratic rainfall pattern and prolonged droughts that make irrigation agriculture very attractive (MoFA, 2013). The regions were also purposively selected due to the location of Tono irrigation scheme in the Kasena-Nankana municipality of the Upper East region and the Bontanga irrigation scheme in the Kumbungu District of the Northern region. Relative to other irrigation schemes in Ghana, the irrigation scheme in the study areas is the gravity type. It is often associated with lower initial investment

costs, and minimum water loss inefficiencies, which allow farmers to save money and labour.

The Tono irrigation scheme is one of the largest irrigation dams in West Africa covering a potential area of about 3840 ha with a developed or irrigable area of about 2490 ha of the Upper East region. The construction of the project started in 1975 by the Government of Ghana and was completed in 1985. Currently, it is under the management of Irrigation Company of Upper Region. The gravity irrigation scheme is about 3.2-kilometre-long dam stretch serving about seven communities in the Kassena-Nankana district, including a number of other smaller villages within the catchment area. The Tono irrigation scheme is unique from other schemes in Ghana in that land holding is large (i.e. minimum 0.2 ha–4 ha). In addition to lower irrigation service charge per farmer, almost every community in the catchment area of the scheme has silos, farm houses or warehouses for storage purposes and a rice mill. The Bontanga irrigation scheme on the other hand, covers about 570 ha of potential area with an estimated developed or irrigable land area of 570 ha. Its construction by the Ghana Government started in 1978 and was completed in 1983. The gravity scheme consists of an earthen dam that incorporates two off-takes, a spillway in the embankment and controls the top water level in the reservoir.

About five out of the seven communities along the Tono irrigation scheme were randomly sampled. From four of the selected communities, 65 rice farm households were randomly selected and 87 farm households from one community making a sample size of 347 in Tono. Similarly, three communities out of five communities along the Bontanga irrigation scheme were randomly selected. From each of the 3 sampled communities, 81 households were randomly selected making a sample size of 243 in Bontanga. A total of 590 rice farm households were sampled for the study, among which 240 were IMT scheme participants and 350 were IMT scheme non-participants. The Tono irrigation scheme area had relatively higher sampled farmers due to the proportional representation of the irrigation farmers under the two irrigation schemes. Thus, the different sample sizes for communities and households were based on proportional sampling (Kothari, 2004). It is important to mention that farmers whose farmlands are not within the reach of the irrigation scheme were not considered in the study. The survey was conducted by trained enumerators. Prior to the data collection, the survey instruments were pretested in the sampled study districts. The data collection took place between December 2016 and January 2017.

The descriptive characteristics of the variables used in the analysis are presented in Table 2. We employed the *t*-test to examine whether there are significant differences between the averages of participants and non-participants characteristics. The estimated mean differences show that there are statistical differences between the IMT scheme participants and non-participants in terms of their age, gender, years of schooling, household size, farm size, quantity of weedicides applied, quantity of seeds used, labour input, use of improved seeds, use of animal traction, membership of farmer-based organization, extension contact distance to nearest MoFA office, access to credit and perceptions about the IMT schemes. No statistical differences exist between the IMT scheme participants and non-participants in terms of quantity of fertilizer applied, distance to district capital market, participation in off-farm work and ethnic representation. Averagely, the number of years of schooling of the IMT scheme participants is about 7 years compared to 5 years for non-participants. Non-participants have significantly smaller household sizes compared to participants. Participants in the IMT scheme cultivate about 1.01 acres more rice fields than non-participants.

Ownership of bullocks tends to be higher for participants than non-participants. Participants in the IMT scheme use more improved seeds but less labour input than non-participants. Compared to participants, non-participants in IMT scheme perceive water usage fees to be high. The proportion of participants who perceive the IMT scheme to be beneficial is higher than that of non-participants. Relative to non-participants, more IMT scheme participants perceive that there is

Table 2
Descriptive statistics of variables used in the analysis.

Variable	Description	Participants(N = 240)	Non-participants N = 350)	Mean difference
Outcome indicators				
Yield	Rice output (kg/acre)	3056.88	2621.14	435.73***
Net returns	Revenue less variable input costs per hectare (GH¢/acre)	3018.79	2504.20	514.59***
Personal & household characteristics				
Age	Age of respondent (years)	41.50 (8.15)	51.09 (13.15)	−9.59***
Gender	1 if farmer is a male, 0 otherwise	0.68(0.48)	0.74(0.50)	−0.06*
Education	Years of formal schooling	7.30 (1.11)	5.21(1.01)	2.09**
Household size	Number of people in the household	10(2)	6(5)	4 ***
Farm & plot level characteristics				
Farm size	Rice area cultivated (acres)	3.15(1.87)	2.14(1.75)	1.01***
Fertilizer	Quantity of nitrogen fertilizer (kg/acre)	64.62(26.03)	63.66(34.43)	0.97
Weedicide	Quantity of weedicide applied (kg/acre)	4.61(2.41)	5.01(2.51)	−0.40*
Seeds	Quantity of seed used (kg/acre)	60.54(3.11)	50.34(2.87)	10.20***
Labour	Labour input in person days	28.42(15.92)	31.97(19.97)	−3.55**
Animal traction	1 if farmer owns bullock, 0 otherwise	0.94(0.33)	0.74(0.36)	0.23***
Improved seeds	1 if farmer used improved seed, 0 otherwise	0.88(0.04)	0.64(0.03)	0.24***
Institutional characteristics				
Credit access	1 if farmer access credit, 0 otherwise	0.62(0.22)	0.88(0.09)	−0.27***
Extension access	1 if farmer has access to extension services, 0 otherwise	0.72 (0.42)	0.49(0.47)	0.23**
FBO	1 if member of farmer-based organization, 0 otherwise	0.95(0.34)	0.89(0.21)	0.09*
Chieftaincy	1 if farmer belongs to any chieftaincy group, 0 otherwise	0.70 (0.42)	0.58(0.23)	0.12***
Off-farm employment	1 if farmer participates in off-farm work, 0 otherwise	0.38(0.12)	0.33(0.10)	0.05
Ethnicgp	1 if farmer belongs to the Dagomba ethnic group in the area, 0 otherwise	0.85(0.12)	0.88(0.09)	0.03
Distance-dcmarket	Distance to district capital market in km.	6.60(2.15)	6.34(2.51)	0.27
Distance-MoFA	Distance to the nearest MoFA office in km	7.22(3.13)	10.01(4.85)	−2.88***
IMT benefit perception	1 if farmer agrees that IMT scheme is beneficial, 0 otherwise	0.87(0.23)	0.46(0.33)	0.36***
Water usage fees	1 if farmer rates water user fee per hectare as higher, 0 otherwise)	0.54(0.32)	0.88(0.45)	−0.34***
Timely supply of water	1 if farmer agrees that there is timely water supply from the scheme, 0 otherwise	0.81(0.55)	0.53(0.22)	0.28**
Availability of water I	1 if farmer agrees that water is available at initial stage of crop growth, 0 otherwise	0.89 (0.43)	0.59(0.32)	0.30**
Availability of water II	1 if farmer agrees that water is available at second stage of crop growth, 0 otherwise	0.92 (0.40)	0.57(0.45)	0.35**
Availability of water III	1 if farmer agrees that water is available at third stage of crop growth, 0 otherwise	0.84 (0.33)	0.54(0.52)	0.30**
Location-specific variables				
Tono	1 if farmer is located in the Tono irrigation scheme catchment area, 0 otherwise	0.59(0.02)	0.58(0.01)	0.01
Bontanga	1 if farmer is located in the Bontanga irrigation scheme catchment area, 0 otherwise	0.41(0.01)	0.42(0.01)	−0.01

*, ** and *** indicates significance at 10 %, 5% and 1% levels.
Average Exchange rate: 1 US\$=GH¢4.27 in January 2017.

timely water supply from the scheme. The results in Table 2 also show that the sampled IMT scheme participants obtain higher yields and net farm returns than the non-participants. The significant difference in yield and net farm returns cannot be attributed to participation in the IMT irrigation scheme since there are no information on counterfactual effect (Abdulai and Huffman, 2014; Donkor et al., 2016; Food and Agricultural Organization of the United Nations [FAO], 2007).

5. Results and discussion

5.1. Determinants of participation in IMT scheme

The empirical results from the ESR are discussed in this section. The first columns of Table 3 and Table 4 show the estimates from the selection models. The likelihood ratio test statistics for joint independence indicate that the equations are dependent. The chi-square statistics indicating the over-identification in the yield and net farm returns models are not significant even at the 10 % level. This result implies non-rejection of the null hypothesis of influence of the instruments on participation in the IMT scheme.

The statistically significant covariance terms for the participants in Table 3 ($\rho_{PA} = -0.642$) and for the participants in Table 4 ($\rho_{PA} = -0.633$) imply self-selection into participation in the IMT scheme by the rice farmers. This also suggests that participation in the IMT scheme may have different impact on non-participants, should they agree to participate in the IMT scheme. This concurs with findings of Sam-Amoah and Gowing (2001) who found that IMT participation led to increase in yield

of farmers at Dawhenya Irrigation Scheme. The negative sign of ρ_{PA} is an evidence of positive selection bias and that rice farmers whose yields and net farm returns are above average are favourites to participate in the IMT scheme. This is not surprising considering the fact that previous studies have shown that IMT have proved to increase operation and management expenditure to farmers and hence will favour above average farmers (Food and Agricultural Organization of the United Nations [FAO], 2007;Namara et al. 2010). The insignificant covariance term ρ_{NP} implies that without participation in the IMT scheme, the behaviour of both participants and non-participants are similar. As expected, off-farm employment and extension access are significantly endogenous in Ghana (see Appendix A1). The estimated coefficients of the residuals of the two potential endogenous variables in Tables 3 and 4 are not significant, suggesting that accounting for possible endogeneity of the two variables in the function postulated to explain the IMT scheme participation is statistically appropriate and supports previous works by Donkor et al. (2016) and Issahaku and Abdulai (2020) in Ghana.

In terms of determinants of participation in the IMT scheme, the results of the selection equation which are interpreted as normal probit estimates shows that the coefficient of the gender variable is positive and statistically significant. This suggests that male-headed households are more likely to participate in the IMT scheme and supports previous findings by Doss and Morris (2001). In the Ghanaian traditional setting, particularly in the Northern regions, certain gender roles limit females from taking independent decision to participate in such irrigations schemes. The coefficient of the farm size variable is positive and significantly different from zero, implying that farmers with large farm

Table 3
Impact of irrigation management transfer scheme participation on yields.

Variable	Selection	Yields	
		Participants	Non-participants
Constant	−0.384 (−1.58)	−1.307 (−1.46)	1.443*** (3.62)
Personal/household characteristics			
Age	−0.105 (−1.58)	0.195** (2.50)	−0.165 (−1.46)
Gender (male)	0.238** (2.36)	0.163(1.18)	0.172(1.26)
Number of years of schooling	0.456** (2.45)	3.6655* (2.93)	4.167** (2.47)
Household size	0.462(0.36)	0.048**(2.11)	0.015* (1.65)
Plot/farm-level characteristics			
Farm size	0.298** (2.06)	0.466** (2.36)	−0.332** (2.14)
Fertilizer	0.475 (1.16)	1.168* (1.67)	0.387 (1.57)
Fertilizer price	0.148 (1.28)	−0.239** (−2.63)	−0.141** (−2.47)
Weedicides	0.434** (2.36)	1.962** (2.37)	2.218** (2.18)
Seeds	0.239** (2.45)	0.214** (2.33)	0.183* (1.74)
Improved seed	1.214* (1.91)	3.558** (2.36)	2.534** (2.37)
Labour wage	−0.122 (1.27)	−1.571** (−2.46)	−1.702** (−2.28)
Labour input	0.030(0.18)	0.017(0.07)	0.021(0.24)
Animal traction	1.101** (2.18)	3.242** (2.37)	1.237 (1.33)
Institutional characteristics			
Credit access	0.423** (2.45)	3.347** (2.19)	2.698** (2.28)
Extension access	0.366** (2.26)	0.875** (2.32)	0.474* (1.75)
Off-farm employment	0.449*** (3.85)	0.563**(1.99)	0.854(1.09)
FBO	1.425*** (3.21)	0.314** (2.33)	0.183 (1.44)
Perception indicators			
Water usage fees	−0.217** (2.38)	1.456*** (4.00)	−1.883(1.44)
Timely water supply	0.316** (2.021)	2.112**(2.44)	0.543(0.21)
Availability of water in stage I of crop growth	0.374*** (4.05)	4.765*** (2.99)	3.221 (0.97)
Availability of water in stage II of crop growth	0.892** (2.27)	2.555**(2.09)	1.782(0.33)
Availability of water in stage III of crop growth	0.477*(1.81)	4.024*** (3.61)	0.831(1.28)
Location variables			
Tono	0.158*** (3.11)	2.342*** (3.23)	3.761*** (4.78)
Residuals			
Off-farm employments	0.433(1.52)	0.023(0.99)	0.012(0.89)
Extension contact	0.569(1.09)	0.140(1.59)	0.132(1.09)
Excluded variables			
Chieftaincy	0.217** (2.38)		
Benefit perception	1.323*** (3.14)		
LR test of independence	29.93***		
Log likelihood	−188.47		
χ^2 for overidentification	0.814 (1.57)		
lns0			−0.641*** (4.15)
ρ_{NP}			−0.255(-0.97)
lns1		−1.411*** (-9.44)	
ρ_{PA}		−0.642** (2.30)	

*, ** and *** indicates significance at 10 %, 5% and 1% levels.

Table 4
Impact of irrigation management transfer scheme participation on net returns.

Variable	Selection	Net Returns	
		Participants	Non-participants
Constant	−0.134* (-1.68)	−0.127* (−1.72)	0.243** (1.97)
Personal/household characteristics			
Age	−0.303 (−1.48)	0.295* (1.91)	0.045 (1.66)
Gender (male)	0.229*** (2.82)	0.150(0.56)	0.177(1.08)
Education	0.536*** (2.49)	4.055*** (2.93)	1.167** (2.46)
Household size	0.011(0.01)	0.113(0.05)	0.139(0.07)
Plot/farm-level characteristics			
Farm size	0.478** (2.52)	0.446* (2.66)	−0.122** (2.14)
Fertilizer	0.475 (1.16)	0.668* (1.68)	0.387 (1.57)
Fertilizer price	0.148 (1.28)	−0.639** (−2.63)	−0.341** (−2.45)
Weedicides	0.434** (2.36)	1.962** (2.37)	2.218** (2.18)
Seeds	0.339** (2.45)	0.414** (2.33)	0.233* (1.74)
Improved seed	1.214* (1.81)	2.558** (2.46)	2.004** (2.47)
Labour wage	−0.132 (1.29)	−1.121** (−2.45)	−0.702** (−2.38)
Labour input	0.062 (1.45)	2.114 (1.54)	0.249 (1.45)
Animal traction (Bullock)	0.101** (2.28)	0.242** (2.47)	0.237 (1.33)
Institutional characteristics			
Credit access	0.523** (2.45)	2.307** (2.33)	0.498** (2.38)
Extension access	0.406** (2.46)	0.555** (2.32)	0.424* (1.78)
Off-farm employment	1.051*** (2.99)	0.343** (2.59)	0.234 (1.58)
FBO	0.532** (2.22)	0.413*** (3.05)	0.129(1.07)
Perception indicators			
Water usage fees	−0.315*** (3.38)	2.467*** (3.59)	0.367(0.98)
Timely water supply	0.413** (2.05)	5.666**(2.57)	1.095(1.45)
Availability of water in stage I of crop growth	0.574*** (3.25)	6.210*** (5.34)	0.994(1.09)
Availability of water in stage II of crop growth	0.992** (2.46)	3.330*** (3.23)	1.650(0.99)
Availability of water in stage III of crop growth	0.377* (1.83)	6.443*** (2.98)	2.432(1.55)
Location variables			
Tono	0.732*** (3.04)	2.347*** (2.89)	1.786* (1.87)
Residuals			
Off-farm employments	0.256(0.89)	0.233 (1.63)	0.185 (1.58)
Extension contact	0.847(1.55)	0.413 (1.44)	0.254 (1.48)
Excluded variables			
Chieftaincy	0.313** (2.25)		
Benefit perception	0.451*** (2.55)		
LR test of independence	29.53***		
Log likelihood	−157.66		
χ^2 for overidentification	0.775 (0.87)		
lns0			−0.451*** (-3.15)
ρ_{NP}			−0.433(-0.67)
lns1		0.644*** (-9.21)	
ρ_{PA}		−0.633** (2.43)	

*, ** and *** indicates significance at 10 %, 5% and 1% levels.

sizes are more likely to participate in the IMT scheme. Extension access is significantly different from zero suggesting that farmers with extension access have higher probability of participating in the IMT scheme. This is in concordance with the work of Donkor et al. (2016) who found that access to agricultural services impacts significantly on adoption of productivity enhancing technologies among rice farmers in Ghana.

The statistically significant coefficient of the variable representing animal traction implies that farmers owning bullocks are more likely to participate in the IMT scheme. This empirical result is particularly interesting for policy in Ghana as it suggests that in the absence of tractor or mechanized services in Northern Ghana, rice farmers could use animal traction, specifically, bullocks to repair and maintain the irrigation canals and ridges (Houssou et al., 2013), which aids IMT scheme participation. The empirical results also suggest that non-credit constrained farmers are more likely to participate in the IMT scheme, which emphasizes the relevance of liquidity constraints in irrigation farming (Kassie et al., 2011). We also found that the participation in an off-farm employment tends to enhance participation in IMT scheme and this in accord with Rakshandrah and Abdulai (2015). The result on the education variable lends credence to the hypothesis that highly educated farmers are more likely to participate in the IMT scheme. Huffman (2001) argued that farmers' participation in new and sustainable technologies is enhanced through accumulation of human capital, notably, education. The empirical results also indicate that farmers who belong to farmer-based organizations are more likely to participate in the IMT scheme. This finding supports the hypothesis that social capital enhances information sharing, which in-turn facilitates adoption of irrigation technology and diffusion (Genius et al., 2014).

The positive significant coefficient of the Tono variable suggests that the location of the irrigation scheme plays crucial role in the decision of the rice farmers to participate in the IMT scheme. This unique result from our study implies that disparity in the access to water resources, the type and nature of the IMT schemes existing in different farming communities in developing countries may contribute significantly to participation in IMT schemes. Another interesting finding from our study are that farmers using more weedicides, seed per unit area and improved seeds are more likely to participate in the IMT scheme than non-participants. Thus, farmers who are associated with high input use intensity are more likely to participate in the IMT scheme.

Based on earlier pilot study as reported by the Food and Agricultural Organization of the United Nations [FAO] (2007), it was found that yield and income were reduced after IMT and part of the reasons were associated with quality of service and maintenance of the irrigation facilities. Therefore, we first assessed farmers' perception of the irrigation facilities and the results indicate that farmers' participation in the IMT scheme is highly dependent on the perception on the viability of the IMT scheme. Promoting a positive perception towards IMT schemes among irrigation management authorities and farmers could influence them to participate in irrigation management (Levidow et al., 2014). Specifically, the results indicate that high water usage fee exerts a negative effect on the likelihood of the rice farmers to participate in the IMT scheme, whilst adequate water availability at the critical stages of rice production and timely water supply from the irrigation scheme increase the likelihood of the farmers to participate in the IMT scheme. Participation in the IMT scheme therefore hinges on the farmers' assessment on timeliness and availability of water supply for irrigation agriculture.

5.2. Determinants of rice yield and net revenue

Other interesting results worth discussing are the factors that influences rice yield and net returns (see last two columns of Tables 3 and 4). These results provide further insights into how productivity from the irrigation schemes can be enhanced besides the IMT policy. We find that age of farmers contribute significantly to higher yields and net farm returns of the IMT scheme participants. The household size variable exerts a positive effect on rice yields of both participants and non-

participants. Farm size shows positive and significant impacts on participant's yield and net farm returns whereas we found an inverse relationship for non-participants. The inverse relationship between farm size and rice yields among non-participants of the IMT scheme agrees with the study by Chen et al. (2011). Another striking result is that an increase in farm size of the rice farmers tend to increase rice yields and net farm returns among participants of the IMT scheme. What this finding suggests, and which adds to the literature on IMT policies is that relatively large farms tend to be more productive and viable under IMT schemes.

The empirical results further show that education and extension access have positive impacts on yields and net farm returns for both participants and non-participants of the IMT scheme. Education and knowledge acquisition through extension contacts contribute significantly to welfare gains (Abdulai et al., 2011; Croppenstedt et al., 2003). Ownership of bullocks tends to exhibit positive impact on rice yields and net farm returns of participants of the IMT scheme. Again, confirming our result on potential bullock use in irrigation farming, the rice farmers participating in the IMT scheme tend to use animal traction to improve rice yields and net farm returns in the Upper East and Northern regions of Ghana. Credit access and off-farm employment participation exhibit significant positive impacts on yields and net farm returns of IMT scheme participants and non-participants and these are consistent with the findings of Abdulai and Huffman (2014). Non-credit constrained farmers and those who particularly participate in off-farm work could raise enough cash to purchase variable inputs to improve productivity. Our empirical results also indicate that members of farmer-based organizations who participate in the IMT scheme tend to have higher net farm returns. Smallholder farmers operating within FBO networks in developing countries tend to have easy control and access to markets in terms of pricing of products, which in turn boost their welfare (Markelova et al., 2009).

Participants in the IMT scheme located in the Tono irrigation scheme area tend to have higher rice yields and net farm returns compared to those in the Bontanga irrigation scheme area probably due to the effective management and water distribution arrangements by water users in Tono (MoFA, 2013). This is an important result for irrigation management transfer policy in that the IMT scheme participants in the Tono area, apart from regular maintenance of the canals and head works by the Irrigation Company of Upper Region, have lower water usage fees and timely supply of irrigation water at the three critical periods of rice growth due to the capacity of the dam compared to the IMT scheme participants in the Bontanga area.

The labour wage and fertilizer price variables exhibit negative significant impacts on rice productivity and net farm returns. The practical implication of these results is crucial to IMT policy in Ghana. With the recent implementation of fertilizer subsidy policy by the Government of Ghana, targeting IMT scheme participants would increase participation and improve yields and net farm returns of smallholder rice farmers in Northern Ghana. We also find that the IMT scheme participants and non-participants who use more weedicides per unit area and improved seeds tend to have higher yields and net farm returns. Also, evident from the result is that IMT scheme participants tend to have higher yields and net farm returns as water usage fee increases. Zhang et al. (2013) argue that in China, water usage fee is directly linked to efficient irrigation water delivery services, which could impact positively on productivity of water users. Our empirical results further reveal that timely water supply, adequate water availability and water availability at critical stages of rice production exert positive impacts on yields and net farm returns of IMT scheme participants.

5.3. Impact of IMT participation on yield, net returns and scale productivity

The estimates of ATT from the ESR in Table 5 generally reveal significant positive impacts of IMT scheme participation on rice yields and

net farm returns. Notably, the results indicate significant differences in yields and net farm returns for the IMT scheme participants and non-participants. The causal effects of participating in the IMT scheme on yields is 1524.05 kg/acre and on net farm returns is GH¢622.16 per acre. These findings suggest that participating in the IMT scheme could improve the welfare of smallholder farmers in sub-Saharan Africa in general (Kassie et al., 2011), and Ghana in particular. The increase in yield is in line with Sam-Amoah and Gowing (2001) at the Dawhenya Irrigation Scheme. However, this is contrary to the findings of Food and Agricultural Organization of the United Nations [FAO] (2007). The increase in yield in this study may be attributed to the improvement in the water delivery at critical stages of crop growth and timely water supply now observed at the schemes investigated in this study.

In the present paper, the relationship between the scale of rice farms and productive resources under the IMT scheme is analysed using the ATT for rice farmers who cultivate more than 1.2 acres and those who cultivate less than 1.2 acres of rice fields. The empirical results from the ESR in Table 5 show that IMT scheme participants cultivating more than 1.2 acres obtain 503.57 kg of rice per acre more than non-participants who cultivate rice fields above 1.2 acres. In terms of net farm returns, the causal effect of IMT scheme participants cultivating more than 1.2 acres is GH¢628.64 per acre. This suggests that participating in the IMT scheme assisted the farmers cultivating more than 1.2 acres to increase rice yields and net farm returns by 13 % and 24.20 % respectively. For rice farmers cultivating less than 1.2 acres, the causal effects of IMT scheme participation on yield is 15.50 % increase and on net farm returns is 36 % increase. These results clearly suggest that farmers cultivating above 1.2 acres obtain substantially higher yields and net farm returns than those cultivating below 1.2 acres. This also indicates that it is more viable to operate relatively large rice farms under IMT schemes as proposed by some studies on IMT policies in Asia, specifically in Taiwan and Sri Lanka (Sakthivadivel et al., 2001) and in India (Sampath, 1992; van Koppen et al., 2003). These findings suggest that farmers participating in IMT schemes in Africa in general, and northern Ghana in particular, will be able to improve their welfare in terms of yields and net farm returns under relatively large-scale rice fields.

Table 5
Average treatment effects of IMT scheme participation on yields and net returns.

	Participants N = 240 (41 %)	Non-participants N = 350 (59 %)	ATT	t-Value	% change
Full sample					
Yields (kg/acre)	3848.73	2324.68	1524.05***	20.35	39.56
Net returns (GH¢/acre)	2537.33	1915.17	622.16***	11.83	24.52
Farm size > 1.2 acres rice field N = 236(40%)					
Yields (kg/acre)	3889.90	3386.33	503.57***	10.11	13.00
Net returns (GH¢/acre)	2597.55	1968.91	628.64***	13.99	24.20
Farm size <1.2 acres rice field N = 354(60%)					
Yields (kg/acre)	2945.58	2488.76	456.82***	11.98	15.50
Net returns (GH¢/acre)	1659.99	1069.55	590.44***	10.01	35.57

*, ** and *** indicates significance at 10 %, 5% and 1% levels.
Average Exchange rate: 1 US$=GH¢4.27 in January 2017.
Farm size categorization is based on the standard set by Statistics, Research and Information Directorate of MoFA.

5.4. Trends in yield and income from IMT (1999–2016)

In addition to the cross-sectional analysis, we looked at the trends in rice yield and income under IMT in the study areas using time series data obtained from the IMT management (see Figs. 1 and 2). As shown in Fig. 1 and consistent with previous studies on IMT impact on yield in Ghana (Food and Agricultural Organization of the United Nations [FAO], 2007; Namara et al., 2011; Sam-Amoah and Gowing, 2001), the early years of 1999–2008 recorded a decrease in yield in Tono. Similar decrease in yields were recorded in Bontanga from 1999. The decrease in yield were attributed to poor operation and management, lack of technical capacities in the early years of IMT policy (Food and Agricultural Organization of the United Nations [FAO], 2007; Namara et al., 2011). Some insignificant increases in yield occurred from 2002 to 2004 in Bontanga. From 2008–2016, yields started rising in both schemes and these increases in yield might be due to improvement in operations, management and technical capacities. This is confirmed by our descriptive findings which showed that farmers perceive that there is timely supply of water and good delivery of water at critical stages of crop growth. Yields in Tono were higher than that of Bontanga. It is important to mention that other factors such as use of improved rice varieties and farm management practices may have cumulative effects on crop yield.

In terms of income, similar patterns were observed in the study areas (see Fig. 2). Income from rice decreased from 1999 to 2003 and increased in 2004 but dropped again till 2008 in Bontanga. In Tono, slight increases income were observed from 1999 to 2008. From 2008, significant increases in income were recorded in both schemes with farmers in Tono attaining higher amounts relative to farmers in Bontanga. The increase in income recorded from 2008 corresponds with the increases in yield. Part of the increase in farm income may be due to the promotion of locally produced rice by the flagship agricultural transformation program focusing on developing the rice sector (MoFA, 2017).

6. Conclusions and policy implications

Results of this study advocate that, in an era of climate change, participation in IMT schemes can significantly enhance rice yield and income, which in turn can improve the welfare of farmers to ensure farming households are food secure and escape poverty trap. However, it is worth mentioning that the increase in yield and income of participants of IMT are not only linked to a more consistent or reliable water supply under IMT schemes, but also connected with investment in inputs, improved management practices and reducing post-harvest losses. Of relevance to policy and management decision is the finding that participation in the IMT scheme tends to favour farmers who are more productive, compared to below-average farmers, which implies that productive farmers have comparative advantage in terms of irrigation water productivity in respect of rice and net farm returns. Given the significant improvement in yields and net farm returns arising from participating in the IMT scheme, agricultural water resource managers, development partners, governments and policy makers should encourage smallholder farmers to participate in IMT schemes. In order to lift the performance of below-average farmers, government subventions can target this category of farmers.

The second implication relates to the revealed selection effect for the impact of IMT scheme participation on rice yields and net farm returns. The practical implication is that assessing the impact of farmers' participation in IMT scheme on outcomes without considering sample selection bias may infer misleading policy implications. This finding provides justification for proper impact evaluation method to unpack the precise impact of IMT. This also provides important information and support for the current quest for efficiency, sustainability and increased agricultural productivity of water use by water managers, users, governments, institutions, and various policy makers, given the current and
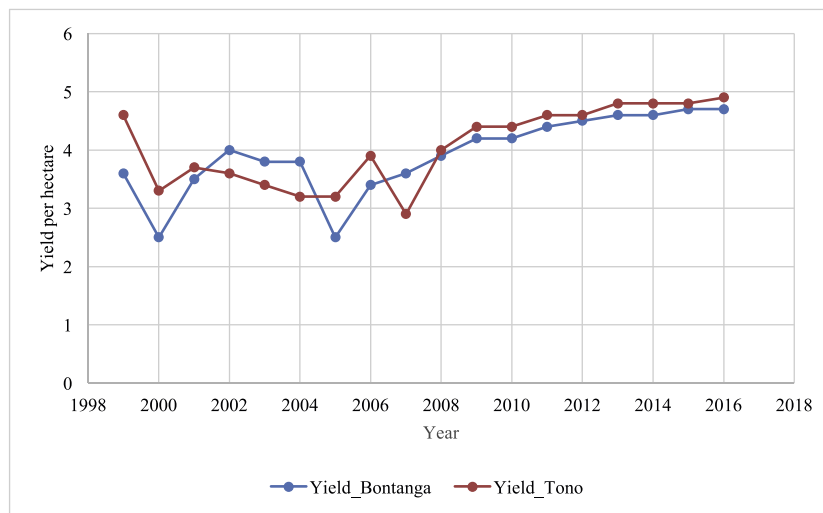
Fig. 1. Trends in rice yields under IMT from 1999-2016.

future water scarcity situation in sub-Saharan Africa in general, and Ghana in particular.

Understanding the scale of rice production under IMT has both theoretical and practical implications. Another insight worth mentioning is the finding that producing on relatively large farm sizes is viable. Thus, the welfare of IMT scheme participants can potentially improve if they operate on large scale under IMT. This insight can be utilised by the Ministry of Food and Agriculture, water users associations and policy makers when designing water and land use policies that will enhance farmers yield, net returns and welfare. We suggest that future implementation of IMT schemes in Africa in general, and Ghana in particular, should pay attention to interventions that promote economically efficient scale of rice production.

Further implications relate to the provision of insights on drivers of farmers' decision to operate under IMT scheme and farm output. Facilitating easy access to education, credit and extension services, and promoting animal traction are policy alternatives needed to improve participation in IMT schemes with the aim of increasing productivity of rice and net returns arising from irrigation water use among smallholder farmers in developing countries. Also, adoption of improved rice seeds and chemical weed control are relevant drivers for farmers' participation in IMT and these in turn enhance rice yield and net returns. Irrigation management authorities, water managers and policy makers

should strive to ensure timely supply and availability of water at critical stages of rice production. This could be utilised as valuable basis to motivate farmers who quit farming under IMT in early years due to poor service delivery to return back and to attract new farmers within the confines of IMT schemes to join.

In summary, we conclude that participation in IMT scheme enhances rice yield and net returns in Ghana. The increased in yield and net returns are linked to the perceived improvement in water supply and availability of water at critical stages of production as well as personal, farm, institutional and location characteristics. Farmers' decision to operate under IMT schemes are driven by both observed and unobserved drivers. The paper recommends that public-private partnerships should take the lead and drive this policy agenda by creating enabling environment for small-medium-scale rice farmers under IMT schemes to improve their welfare as well as encouraging more farmers within the reach of the irrigation scheme to participate in the IMT. The paper is not without limitations. First of all, our analysis focused only on rice producers. We suggest that future research should examine how IMT participation impacts on yield of other crops like maize, tomatoes and vegetables grown under the IMT scheme. In addition, it is important to mention that besides the net returns and yield used as performance indicators, future studies can consider indicators such as cropping intensity and irrigated area. Finally, differences in goals and aspirations of
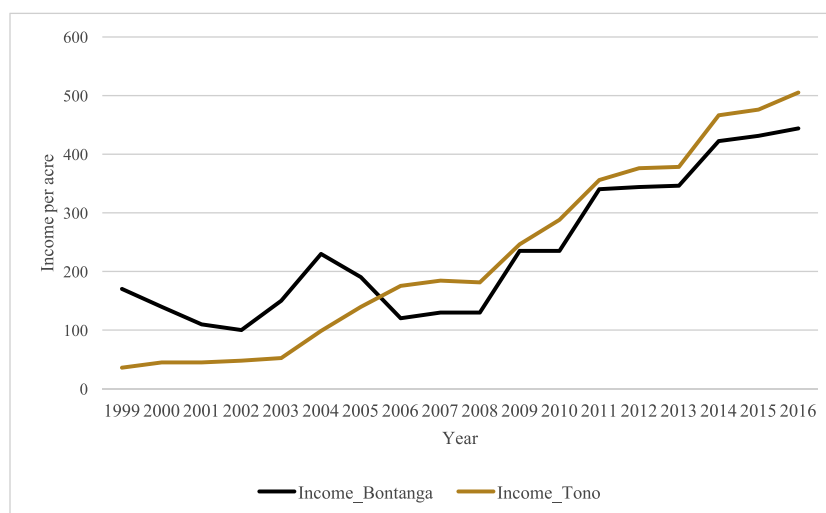

Fig. 2. Trends in income from rice production under IMT from 1999-2016.

both participants and non-participants should be considered in future research since they influence farmers' decision to join IMT or not.

The findings of this study should be considered with some caveats since we relied on cross-sectional data for our empirical analysis. Firstly, panel data would have allowed us to measure the impact from the time the farmers joined the IMT until differences in yield and income became evident. Secondly, a randomized experiment to determine the impact of IMT on yield and income would have been a better measure but data on this was not available. Notwithstanding these caveats, we do not anticipate systematic bias in our analysis. Thus, this study adds to existing knowledge on the strife for participation, improvement and better understanding of irrigation sector reforms as well as relevant factors that hinder or enhance farmers' decision to participate in the irrigation management scheme.

CRediT authorship contribution statement

Enoch Owusu-Sekyere: Conceptualization, Methodology, Formal analysis, Writing - original draft, Software, Validation, Writing - review & editing, Data curation. **Cindy Bibariwiah:** Conceptualization, Investigation, Resources, Data curation. **Victor Owusu:** Conceptualization, Methodology, Project administration, Supervision, Writing - review & editing, Validation. **Emmanuel Donkor:** Software, Writing - review & editing, Validation, Methodology.

Declaration of Competing Interest

The authors report no declarations of interest.

Appendix A1 First stage probit estimates of determinants of extension access and off-farm employment

Variable	Extension visit	Off-farm work
Constant	−1.017*(1.67)	−0.241*(1.65)
Personal/household characteristics		
Age	−0.159***(3.05)	−0.587***(3.16)
Gender (male)	0.614** (2.43)	−0.317*** (3.33)
Education	1.108**(2.34)	0.634*(1.73)
Household size	−0.059(0.89)	0.759**(1.89)
Plot/farm-level characteristics		
Farm size	0.453**(2.08)	0.012(0.71)
Fertilizer	0.043(0.29)	0.434**(2.21)
Fertilizer price	0.131(0.11)	0.127**(2.19)
Weedicides	0.717(0.24)	−0.225***(3.63)
Seeds	0.529**(1.99)	0.132**(2.14)
Improved seed	0.357**(2.49)	0.411(0.29)
Labour wage	−1.007(1.33)	0.231* (1.67)
Labour input	−0.818(1.32)	−0.059**(0.28)
Animal traction (Bullock)	0.144***(3.02)	0.595*(1.69)
Institutional characteristics		
Credit access	0.444(0.38)	0.177**(3.54)
FBO	0.512***(3.20)	−0.138** (2.75)
Distance_dcmarket		0.354***(3.45)
Distance_MoFa	0.116**(2.35)	
Perception indicators		
Water usage fees	0.433(1.38)	−0.112**(2.07)
Timely water supply	0.131(0.14)	0.127(0.13)
Availability of water in stage I of crop growth	0.122(0.22)	0.132(0.29)
Availability of water in stage II of crop growth	0.023(0.59)	0.159 (0.11)
Availability of water in stage III of crop growth	0.327(0.49)	0.310(1.59)
Location variables		
Tono	1.276***(3.12)	0.326***(4.18)
Pseudo-R^2	0.22	0.23
Log-Log likelihood	−298.85	−218.78
Wald chi-square	99.72***	143.12***
Observations	470	470

*, ** and *** indicates significance at 10 %, 5% and 1% levels.

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