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Does investment in motor pump-based smallholder irrigation lead to financially viable input intensification and production? An economic assessment

Does investment in motor pump-based smallholder irrigation lead to financially viable input intensification and production? An economic assessment

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Acronyms

ACSI	Amhara Credit and Saving Institution
ATA	Agricultural Transformation Agency
ATT	Average treatment effect on the treated
CIA	Conditional independence
DECSI	Dedebit Credit and saving Institution
DBE	Development Bank of Ethiopia
IRR	Internal rate of return
LIVES	Livestock and Irrigation Value Chains for Ethiopian Smallholders
MFI	Micro finance institutions
NPV	Net present value
PMS	Propensity score matching method
TLU	Tropical livestock units
UNIDO	United Nations Industrial Development Organization

Abstract

Privately adopted motor pump-based smallholder irrigation is different from conventional irrigation schemes in many ways. Unlike to scheme based irrigation that usually experience financial deficits and complex management bureaucracies, privately owned and managed irrigation technologies avoid problems related with collective action. This study focuses on the impact of motor pump-based smallholder irrigation in input use and production as compared to rainfed production systems and investigates the financial viability of such investments. Data used in this study come from the baseline and motor pump surveys of Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) project conducted in five districts of four LIVES intervention zones conducted in 2014, but in reference to the 2012/2013 production season. The non-parametric propensity score matching (PSM) method was used to assess the effect of motor pump-based smallholder irrigation on input use and production. Following this, we adopt a cost-benefit analysis framework to study whether such investment is financial viable. Results show that as compared to rainfed agriculture, the use of motor pump-based smallholder irrigation leads to significantly higher and financially viable input use and production. Based on different scenarios, the estimated net present values (NPV) computed at 8.5%; 13.9%; 25.9%; 28% and 30% interest rates show investment in motor pump-based smallholder irrigation is financially viable and robust even at high interest rate and volatile market conditions. The data also suggest that an increase in irrigated land leads to a higher profit margin/ha as a result of lower cost/ha and higher gross production values/ha. Despite that over abstraction of water and use of agro-chemicals may result in land degradation and reduced marginal benefits due to loss of micro nutrients and genetic diversity of crop varieties, our analyses fail to capture such external costs.

1 Introduction

Agriculture dominated by smallholder farmers is the main source of income and employment in Ethiopia. Smallholder farmers are rural producers who have limited resource endowment who usually use family labour to operate less than two hectares (Dixon et al. 2003; World Bank 2003; Ellis 1998). The production system is constrained by low and erratic rainfall causing low input use and low agricultural productivity. In Ethiopia, investment in irrigation as a strategy to reduce the negative effect of rainfall variability and low input use has received momentum since recently. Despite considerable efforts have been made, however, current irrigation coverage is low compared to the potential partly because past experience has given emphasis to scheme irrigation which generally is constrained by high investment cost and management complexity. For example, Awulachew et al. (2007) documented that only 5–6% of Ethiopia's irrigation potential was developed through public investment in small, medium, and large-scale irrigation schemes implying that has largely ignored the proliferation of individually managed smallholder private irrigation.

Studies from other parts of the world (Rydzewski 1990; Fan and Hazell 2001; Shitundu and Luvanga 1998) also argue that for a greater impact of irrigation, the financial gains need to be spread through increased access and participation of many smallholder farmers where the use of motor pumps has greater ability to do this than scheme-level irrigation because compared to smallholder private irrigation, communal irrigation schemes are capital intensive and limited in land coverage. Similarly, studies from sub-Saharan Africa (Takeshima et al. 2010a, 2010b and Dauda et al. 2009) documented that in Zimbabwe, private irrigation technologies allow smallholder farmers to adjust irrigation schedules to respond to localized events and are more likely to bring higher returns per hectare than community-managed irrigation schemes. Indian experience also shows that investments in scheme level irrigation in the 1970s and 1980s was a disappointing experience in meeting targets due to high investment and management costs that has promoted a shift to small-scale irrigation (Adams 1991; Lam 1996). In general, compared to large-scale irrigation schemes, privately-managed smallholder irrigation has higher productivity and profit margins (Ofosu et al. 2010; D'Souza and Ikerd 1996), because private ownership and operation of technologies avoid problems related with collective action often observed in public or communal irrigation schemes (de Fraiture and Giordano 2014).

Apart from their higher productivity and spread of benefits, individually-operated private irrigation technologies are different from conventional irrigation schemes in many ways, such as: (1) they are initiated and financed by farmers themselves; (2) they are operated and managed by individuals or small self-initiated groups; (3) they irrigate small area of land; (4) they are relatively low-cost; (5) farmers cultivate high value crops for the market; (6) they use diverse water sources directly from nearby sources (such as rivers, lakes, canals, reservoirs or wells); and (7) they are spread spontaneously and unregulated (de Fraiture and Giordano 2014).

However, due to the fact that the spread of private irrigation technologies is spontaneous and unregulated, data on private irrigation technologies in Ethiopia is not readily available. That said, Santini et al. (2011) has estimated the potential for small private motor pump irrigation to be between 1.4 and 2.8 million hectare from which 9 to 18 million people can benefit.

Nonetheless, access to irrigation technologies by itself is not sufficient to increase agricultural production and productivity unless its contribution to increase the use of production enhancing inputs is considered. Different studies (such as Abdoulaye and Sanders 2005; FAO 2005; Fox and Rockstrom 2000; Mikkelsen et al. 2015; Morris et al. 2007;

Shah and Singh 2001; Smith 2004; Wichelns 2003; Yao and Shively 2007) have suggested strong complementarities between irrigation and input intensification that lead to higher productivity and improved efficiency, but requires cautious management. For instance, Fuglie and Rada (2013) reported that in sub-Saharan Africa, yield on irrigated land is 90% higher than on rainfed probably hinting the positive role of irrigation towards input intensification in addition to its role of reducing production risk due to low and variable rainfall. Otsuka and Place (2014) and Sheahan and Barrett (2012), also, argue that input intensification leading to increased agricultural production and productivity occur as a result of technological change like irrigation.

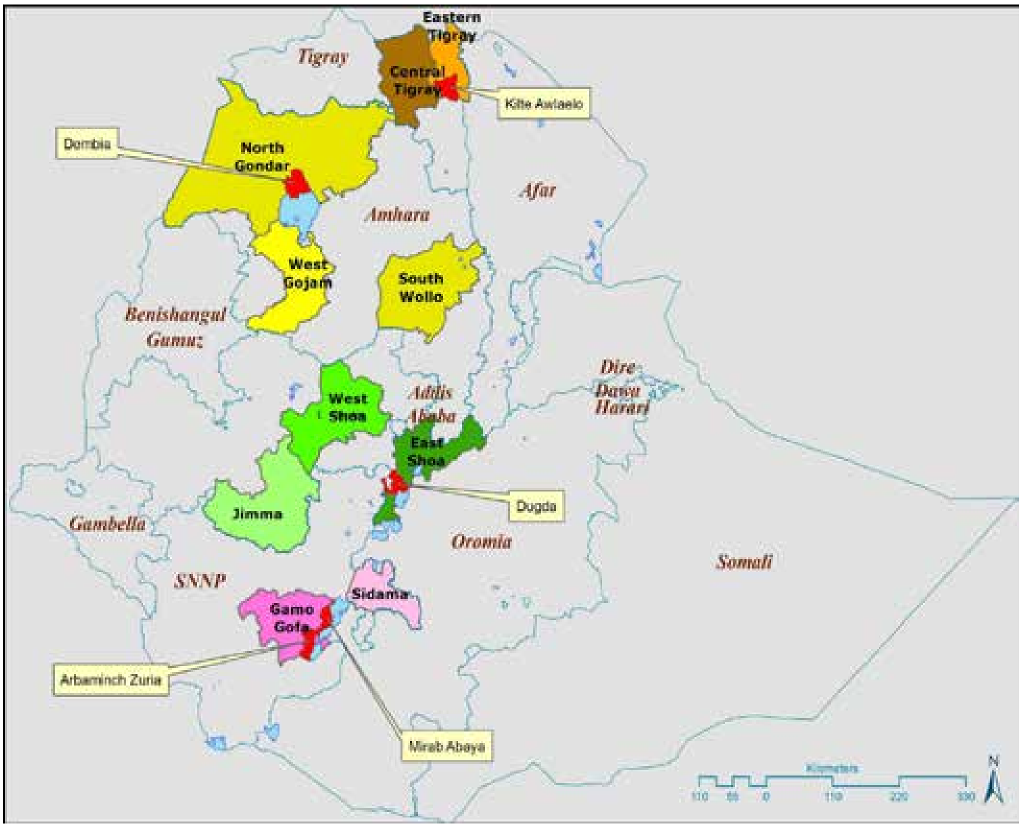
On the other hand, although investment in private irrigation technologies can play an important role in tapping available irrigation potential at low cost and higher efficiency, a combination of technical and economic factors, such as high operation cost and lack of services (maintenance/repair and spare-parts supply services) are potential bottlenecks. Evidence from Tigray (Nata and Bheemalingeswara 2010), for example, shows that farm households which adopted motor pumps to irrigate and produce high value crops often complain about frequent breakdown of pumps and lack of maintenance services, implying that despite the use of self-initiated and financed motor pumps for private irrigation as gaining importance in Ethiopia in recent times, it has not equally led to the emergence of service providing enterprises.

Hence, understanding how investment in motor pump-based smallholder irrigation influence input use and agricultural production/productivity is paramount importance. Likewise, inquiry into whether such investment is worthy investment remains equally important as a guide for future investment decisions. In this regard, the objective of this study is twofold. 1) To assess whether investment in motor pump-based smallholder irrigation contributes to higher input use and high production/productivity; and (2) To assess whether investment in motor pump-based smallholder irrigation is financially viable and thus worthwhile.

2 Data and study area description

Data for this study was obtained from a special study on motor pumps and the LIVES baseline survey. Both surveys were conducted in 2014, but referred to the 2012/2013 production season. Data for the motor pump survey was obtained from randomly selected 400 farm households in five districts of four LIVES intervention zones (Figure 1). However, collected data was limited to irrigated agriculture. Four hundred thirty-six (436) households of the baseline survey conducted by the LIVES project were selected to determine rainfed agriculture. These (baseline) farm households were randomly selected based on proportional to size sampling technique. For sampling purposes, the study districts (Figure 1) were stratified into three agro-ecologies. Data was collected on household characteristics; household asset ownership; farm characteristics including land holding, herd size; and access to physical and institutional infrastructure.

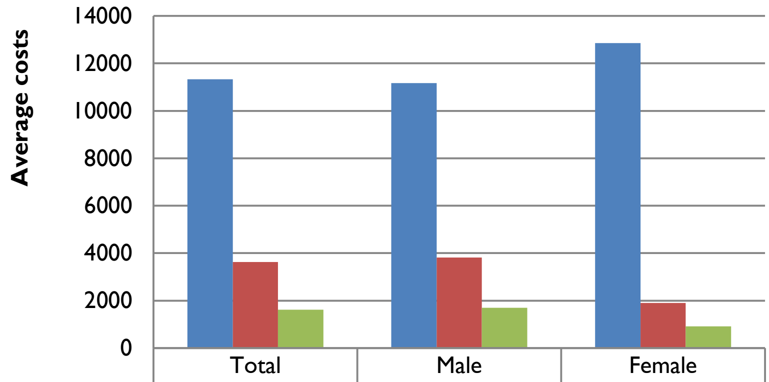
Figure 1: Study districts embeded in LIVES intervention zones.



2.1 Assessment of motor pump adoption and availability of services

Among the total sample households used in this analysis, 400 of them have adopted motor pump for smallholder irrigation purposes. Average cost of a motor pump was about ETB 11,334 (Figure 2). As presented in Figure 2, average cost of fuel consumption and maintenance costs were in the order of ETB 3627 and 1621 /year, respectively, but these may vary depending on the size, model and intensity of use of the technology. Although there are differences costs, disaggregated by gender were not statistically insignificant.

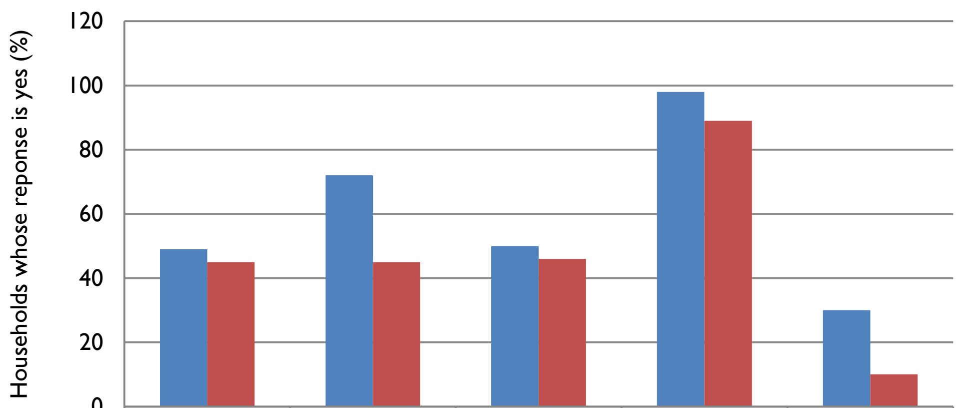
Figure 2: Average investment fuel and maintenance cost of motor pump.



	Total	Male	Female
Average investment cost (ETB/motor pump)	11334	11166	12851
Average fuel cost (ETB/year)	3627	3819	1900
Average Maintenance cost (ETB/year)	1621	1700	911

Figure 3 shows farmer perception in relation to availability of motor pump-use related services. Since delay in maintenance and repair services is critical for irrigation activities, we tried to check the average number of days that motor pump service seekers need to wait before their pump is repaired, and found that they have to wait for about 21 days. Similarly, information from the Ethiopian Agricultural Transformation Agency (ATA) shows that the average waiting time for maintenance and repair services was about 48 days and may suggest that about three to six weeks delay during irrigation season potentially leads to substantial reduction in production and productivity of smallholder farmers.

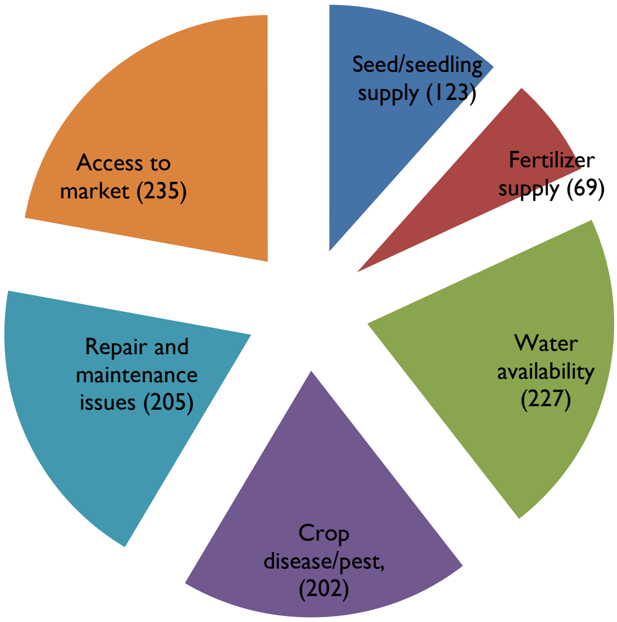
Figure 3: Per cent of sample households who perceive poor availability of services.



	maintenance services is poor	Spare part supply is poor	Instalation services is poor	Trainning service is poor	Credit service is poor
Female	49	72	50	98	30
Male	45	45	46	89	10

Finally, we tried to gather farmer responses and perceptions about three major problems they commonly experienced in their motor pump-use and irrigation activities based on which lack of access to market followed by water shortage, lack of repair/maintenance services and crop disease were the most cited problems (Figure 4).

Figure 4: Problems perceived by motor pump adopters.



3 Estimation strategies

We outline below a propensity score matching (PSM) method to assess whether motor pump-based smallholder irrigation effects in higher input intensification and production. This requires creation of comparable groups among households who adopt and do not adopt motor pump-based smallholder irrigation as an attempt to control for selection biases as well as other observable and unobservable factors that may be correlated with adoption of motor pumps, input use and production. Following the PSM, we also outline the estimation strategy to assess whether investment in motor pump-based smallholder irrigation is financially feasible.

3.1 Propensity score matching method

PSM is a non-parametric estimation method widely used in the impact evaluation literature (Ravallion 2005; Cobb-Clark and Crossley 2003; Heckman et al. 1998). Matching method creates a comparable group from a treated and non-treated sample known as counterfactuals. The basic assumption when using a counterfactual is that the untreated samples approximate the treated samples if they had not been treated (Heckman et al. 1998). In this study, the treatment is motor pump-based smallholder irrigation and the treated are those who invest in motor pump and use it for smallholder private irrigation. For the matching method to be valid, the assumption of conditional independence (CIA) is important to hold true, because CIA argues that the testament is random and conditional on observed variables (X) specified as:

$$\left(Q_0 \perp MP \middle| X\right) \tag{1}$$

Where Q_0 stands for amount of input use and production per hectare and MP for adoption of motor pump-based stallholder irrigation. This assumption implies the counterfactual outcome for the treated group is the same as the observed outcomes for the non-treated group given the control variables (X). The implication is that the counterfactual input use and production per hectare is the same as input use and production level that would have existed if the household had not invested and used motor pump for smallholder irrigation specified as:

$$E\left(Q_0 \middle| X, MP=1\right) = E\left(Q_0 \middle| X, MP=0\right) = E\left(Q_0 \middle| X\right) \tag{2}$$ [1]

The first term of equation (2) represents the counterfactual input use and production per hectare of the treated group and is equal to the observed input use and production per hectare of the untreated (control) group.

This hypothesis rules out selection bias in the use of motor pump for smallholder irrigation and then input use and production gains from motor pump-based smallholder irrigation on the basis of unobservable. The CIA requires that

1. This implies that. $E(\Delta Q|MP=1) = E(Q_1|MP=1) - E(Q_0|MP=0)$ By subtracting and adding, we obtain $E(Q_0|MP=1)$ $= E(Q_1 - Q_0|MP=1) + E(Q_0|MP=1) - E(Q_0|MP=0)$, $= E(\Delta Q|MP=1) + [E(Q_0|MP=1) - E(Q_0|MP=0)]$ where the first term denotes the impact of motor pump-based smallholder irrigation, and the second term, i.e $[.]$., captures the bias. However, if Q0 is the mean of input use and/or production per hectare independent of motor pump use (MP), $E(Q_0|MP=1) = E(Q_0|MP=0)$ i.e., the bias disappears and is identified and is unbiased (Cobb-Clark and Crossley 2003).

the set of X's contain all variables that jointly influence the outcome with no treatment, as well as investment in motor pump-based smallholder irrigation. Under conditional independence, therefore, the average treatment effect on the treated (ATT) can be computed as:

$$ATT = E(Q_1 - Q_0 | X, MP = 1) = E(Q_1 | X, MP = 1) - E(Q_0 | Q_0, MP = 1) \tag{3}$$

However, matching of households based on observables may not be viable when the dimension of control variables is large, hence, to overcome the problem of dimensionality, Rosenbaum and Rubin (1983) argued that one can match along a single index variable given by the propensity score, $p(X)$ which summarizes the multi-dimensional variables. This is the conditional probability that household i has access to motor pump-based smallholder irrigation given the conditioning variables, written as:

$$p(X) = pr(MP = 1)|X \tag{4}$$

Hereafter, ATT in equation (3) can then be written as:

$$ATT = E(Q_1 | p(X), MP = 1) - E(Q_0 | p(X), MP = 1) \tag{5}$$

The intuition of estimating ATT (Eq.5) is to use the outcomes of non-treated households as a measure of what treated individuals would have received had they not received the treatment. For the propensity score to be valid, the balancing properties need to be satisfied implying that two households with the same probability of using motor pump for smallholder irrigation will be placed in the treated (with motor pump-based smallholder irrigation) and untreated (without motor pump-based smallholder irrigation) samples in equal proportions implying that once the propensity score (pscore) is estimated, data is split into equally spaced pscore intervals, indicating that the mean pscore of each conditioning variable is equal for the treated and control households and then a balancing property is established. Since the pscore is a continuous variable, exact matching may not be possible where a certain distance between treated and non-treated is accepted. Hence, households with and without motor pump-based smallholder irrigation were matched based on their propensity scores (pscore) using the nearest neighbour, kernel and stratification matching methods. These methods identify the closest match for each treated household among the non-treated households, and then compute the effect of the treatment in this case, motor pump-based smallholder irrigation as a mean difference of input use and production per hectare. Although each of these methods has its own strengths and limitations; their combined use has an advantage of testing the robustness of estimated results (Becker and Ichino 2002). A brief description of the three matching methods is given below.

- a) *Nearest neighbour matching method:* Each treated observation is matched with an observation in the control group that exhibits the closest propensity score. In nearest neighbour matching, it is possible that the same household in the control group can neighbour to more than one household in the treated group. Therefore, the difference is calculated as the average effect of motor pump-based smallholder irrigation on input use and production per hectare inferred as ATT.

b) *Kernel matching method:* All treated households are matched with households in the control group based on the weighted average that is inversely proportional to the distance between the propensity scores of the treated and control groups.

c) *Stratification matching method:* The dataset is divided into intervals having, on average, the same propensity score. The treated and control groups within that interval are placed under one block, and then the mean difference of the outcome between the treated and control groups provides the average treatment effect of motor pump-based irrigation on input use and production per hectare ATT.

3.2. Financial viability of investments in motor pump for private irrigation

We used the UNIDO (1972) approach in the estimation of NPV and internal rate of return (IRR) as a measure of the financial viability of investment in motor pump-based smallholder irrigation as specified below (Eq. 6).

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+r)^t} \tag{6}$$

Where NPV stands for net present value; n is the time period, B_t stands for benefits at time t; C_t is cost at time t; and r is the real discount rate. The NPV is the present value of net cash inflows generated by smallholder farmers who produce using motor pump-based smallholder irrigation. It is a reliable measure used in capital budgeting because it accounts for temporal changes in the value of money by using discounted annual cash flows.

Data on production, cost of investment (cost of motor pump), and production input like fuel consumption and maintenance/repair costs, labour, fertilizer, chemicals, seed and draft-power were collected. Table 1a and Table 1b summarize average value of production and costs of whole and matched sample household, respectively.

Table 1a: Estimated average value of production and production cost (all sample households)

Production and cost items (ETB)	Per average household			Per hectare		
	Rainfed (N=436)	Irrigated (N=400)	Significance of difference (T-test)	Rainfed (N=436)	Irrigated (N=400)	Significance of difference (T-test)
Value of average Production	38211	90087	4.895***	20075	96865	9.899***
Investment cost of MP	---	11334	NA	0	25850	NA
			Production and operation costs			
Value of fertilize used	1035	3584	4.029***	931	6240	10.563***
Value of agro-chemical	61	3047	3.312**	50	2246	7.887***
Cost of labour	920	7600	9.000***	551	8380	21.096***
Cost of draft power	2981	1712	6.133***	1772	2281	4.862***
Cost of seed	230	351	1.462	156	419	4.211***
Fuel consumption cost	---	3627	NA	0	6504	NA
Maintenance and repair cost	---	1621	NA	0	3181	NA
Total production cost	5227	21542		3460	29251	

Table 1b: Estimated average value of production and production cost (matched sample households)

Production and cost items (ETB)	Per average household			Per hectare		
	Rainfed (N=235)	Irrigated (N=253)	Significance of difference (T-test)	Rainfed (N=235)	Irrigated (N=253)	Significance of difference (T-test)
Value of average production	42728	117494	4.553***	25953	112196	7.684***
Investment cost of MP	0	11245	NA	0	24313	NA
Production and operation costs						
Value of fertilize used	1147	4767	3.402***	1112	7215	8.853***
Value of agro-chemical	73	4493	2.877**	66	2857	6.208***
Cost of labour	1088	9354	6.752***	567	8714	15.353***
Cost of draft power	3175	1868	5.080***	1811	2077	2.083*
Cost of seed	278	381	0.763	184	329	1.809*
Fuel consumption cost	0	3954	NA	0	6484	NA
Maintenance and repair cost	0	1779	NA	0	2832	NA
Total production cost	5761	26596		3740	30508	

Due to lack of evidence related to the use-life of an average motor pump in Ethiopia, we based on previous report (Arbic et al. 2011) from West African experience to set five years as the average use-life of an average motor pump. Arbic et al. (2011) reported that the use-life of motor pumps in West Africa (Burkina Faso, Mali, and Niger) was between two to five years depending on the intensity of use and the degree of maintenance.

The IRR presented in Eq. 2 is defined as the rate of return on an investment that equates the net present value of benefits and costs such that the net present value of the investment becomes zero.

$$IRR = \sum_{t=1}^{n} \frac{B_t}{(1+r)^t} - \sum_{t}^{n} \frac{C_t}{(1+r)^t} = 0 \tag{7}$$

The IRR is equivalent to the discount rate (r) that satisfies equation (Eq 2). For convenience, the ETB was used as the common unit for the financial viability analysis.

4 Descriptive statistics

Table 2 presents comparative statistics of matched households. About 94% of both treated and non-treated of the matched households are male headed and no statistical significant difference exists between the two groups. Similarly, there was no statistical difference in relation to household head's age of the treated and non-treated household group. On the other hand, household size in adult equivalent significantly higher in favour of the non-treated (control) group as compared to the treated group. As compared to the non-treated sample households, the treated sample households were wealthier in capital assets holdings, including value of durable asses, livestock, tropical livestock units (TLU), and land size in hectares. Similarly, households which invest in motor pump-based smallholder irrigation (treated) have used significantly higher input per hectare as compared to the non-treated group except for draft-power (oxen days/ha). This was also true in relation to production per hectare (Table 2).

Table 2: Summary statistics of matched households

Variable	Treated (N=253)	Control (N=231)	Significance of difference (T-test)
Human capital and asset holding			
Household sex (1=male, 0=female)	0.949	0.940	0.395
Household head age (years)	42	44	1.580
Household size in adult equivalent	4	5	4348***
Value of asset holding (ETB)	33,608	19,308	2384**
Livestock holding (TLU)	7	9	3627***
Land holding (ha)	1.285	1.860	3712***

*, **, *** significant difference at 10%, 5% and 1%, respectively

5 Regression results

5.1. Input use and production per hectare

Table 3 presents the non-parametric matching estimates of the effect of motor pump-based smallholder irrigation on agro-chemicals and fertilizer use per hectare.

Based on the different matching methods, we used to assess the robustness of our estimation, the average value of agro-chemical used per hectare on irrigated land is higher than that of rainfed land by about ETB 10,155 to 10,600 (Table 3) and is statistically significant at 1% level of significance. This indicates that relying on selection observables and assuming no selection bias, the mean input use per hectare on irrigated land has significantly increased due to investment in motor pump-based smallholder irrigation. Similarly, fertilizer use per hectare on motor pump-based irrigated land exceeds that of on rainfed land by about 323 to 331 kg/hectare.

Table 3: Impact of motor pump-based smallholder irrigation on chemical and fertilizer use per hectare

Matching method	Treated (N)	Control (N)	ATT	Significance of difference (T-test)
		Value of agro-chemicals use/hectare		
Kernel matching	253	235	10,128(1366)	7.41***
Nearest neighbour matching	253	122	10,600(1371)	7.732***
Stratification matching method	253	235	10,155(1252)	8.113***
		Fertilizer use Kg/hectare		
Kernel matching	253	235	323(61)	5.321***
Nearest neighbour matching	253	122	331 (56)	5.867***
Stratification matching method	253	235	323(61)	5.323***

*** Significant at 1% level of significance. Figures in parenthesis are bootstrapped standard errors

Table 4 presents estimates of the ATT of motor pump-based smallholder irrigation on production/productivity per hectare. Based on the different matching methods adopted for assessing the robustness of the estimated results, the overall average production gain per hectare due to motor pump-based smallholder irrigation ranges between ETB 85,845 and 87,241 per hectare and is statistically significant at 1% level of significance in all matching method results. This may indicate that average production per hectare has significantly increased due to adoption of motor pump-based smallholder irrigation and is consistent with the input use effect of the technology.

Table 4: Impact of motor pump-based smallholder irrigation on agricultural production/productivity per hectare

Matching method	Treated (N)	Control (N)	ATT	Significance of difference (T-test)
Kernel Matching	253	235	87,241 (10,739)	8.124***
Nearest neighbour matching	253	132	85,845 (10,221)	8.399***
Stratification matching	253	235	87,061 (10,719)	8.122***

*** Significant at 1% level of significance. Figures in parenthesis are bootstrapped standard errors

5.2. Financial viability of investment in motor pump for private irrigation

The estimated NPV shows that investment in motor pump-based smallholder irrigation is profitable (Table 5). Although the use-life of a standard motor pump can last for more years, the NPV was computed assuming five years as the use-life of the motor pumps, because it positioned us in a safe side not to overestimate the economic life of such investment and estimated NPV.

Based on our survey data, average investment cost per motor pump and aggregated operation and maintenance costs per hectare was estimated at about ETB 25,850 and 33,003, respectively (for details see Table 5 column 1).

To account for a potential variability in market prices and interest rates, we use different discount rates and scenarios of price/cost variabilities to simulate sensitivity analysis as an effort to examine the robustness of financial viability of investment in motor pump-based smallholder irrigation (Table 5).

For the discount rates (r), we adopt official interest rates of the Development Bank of Ethiopia (DBE) and micro finance institutions (MFIs) (i.e. the Amhara Credit and Saving Institution-ACSI and Dedebit Credit and saving Institution-DECSI). As stated in DBE (2011), the bank is mandated to extend investment credits to credit worthy borrowers and projects that demonstrate robust financially and economically feasibility appraisal. According to DBE (2011), the lowest interest rate to be charged on loans for investment in priority areas is 8.5%. However, despite that investment in agriculture is among the priority areas, it is not clear whether such smallholder investments are among the priority areas to qualify for the bank's viability appraisal standards. Secondly, since DBE's main area of focus is on long and medium-term investment projects, it is less likely for the smallholder farmers to access such strategically designed credit sources. Hence, we considered that the rural MFIs are the main credit sources for household level irrigation technologies. Accordingly, the maximum interest rates that include interest, fees, insurance, taxes and security deposit charged by ACSI and DECSI are 13.9% and 25.9%, respectively.

On top of the official interest rates, we use 28% and 30% of interest rates for sensitivity analysis purpose. In addition to discount rates, since variability in production costs and returns affect the financial viability of investments, we propose different cost and income scenarios to check how investment in motor pump-based smallholder irrigation is sensitive to cost and income changes. In this respect, scenario 1 (Table 5 column 1) is based on the survey (actual) data, while scenario 2 and 3 are based on arbitrary assumptions of increased costs and reduced returns. In an environment of non-random input and output prices and smallholder farmers being price takers, we anticipate a possibility of increased cost and reduced income. Hence, scenario 2 (Table 5 column 2) assumes a 25% increase in cost together with 35% decrease in income (return). On the other hand, although production costs and output prices may continue in an increased and decreased trend, respectively, we assume that income can increased if some of the bottlenecks, such as lack of maintenance/repair services, agronomic practices and market-related issues, can be addressed. Therefore, scenario 3 (Table 5 column 3) assumes a 125% increase in cost and 20% increase in income.

Based on the different scenarios, NPVs that were computed at 8.5%; 13.9%; 25.9%; 28% and 30% interest rates show investment in motor pump-based smallholder irrigation is financially viable and robust even at high interest rate and volatile market conditions. We admit that some of our assumptions are somehow overstated and less likely to happen, but this gives us an idea how far we can recommend such investments even in an exceptionally volatile market conditions.

Table 5: Sensitivity analysis of financial viability of investments in motor pumps for private irrigation[2] (ETB)

Parameters estimated at average	Scenario 1: Estimates based on survey (actual) data	Scenario 2: Cost increased by 25% while income decreased by 35%	Scenario 3: Cost increased by 125% and income increased by 20%
Investment cost/ha	25,850	32,312.5	58162.5
Maintenance and repair cost/ha	3181	39,76.25	7157.25
Fuel consumption cost/ha	6504	8130	14634
Fertilizer cost ETB/ha	6240	7800	14040
Agro-chemicals cost ETB/ha	2246	2807.5	5053.5
Labour cost ETB/ha	7600	9500	17100
Draft-power cost ETB/ha	1712	2140	3852
Seed cost ETB/ha	351	438.75	789.75
Total operation cost/ha/year	33,003	41,255	74259
Production value (benefits) ETB/ha	90,087	58,556.55	108104.4
Net cash flow ETB/annum	57,084	17,301.55	33845.4
NPV (8.5%)	USD 226,893.01	72,532.22	141,588.70
NPV (13.9%)	185,875.21	56,744.61	111,374.18
NPV (25.9%)	124,242.86	33,414.83	66,651.78
NPV (28%)	116,358.23	30,480.87	61,017.82
NPV (30%)	109,447.22	27,922.20	56,101.99
IRR	267%	83%	89%

Besides discount rates, size of land, as a proxy of scale of economics, is assumed to affect the viability of investments. Table 6 presents a financial viability analysis of investment in motor pumps based on different size of irrigated land to capture the effect of scale of economics on the viability of investments[3]. Figures presented in Table 6 are an average per hectare equivalent. Accordingly, our result (Table 6) shows that investment in motor pump is financially viable if the size of irrigated land is equal or greater than a quarter of a hectare (0.25 ha).

Figure 5 shows that average investment cost per ha of irrigated land generally decreases when the size of irrigated land increases. Similarly, operation costs per hectare show a decreasing trend when size of irrigated land increases. Economics of scale is the main reason for this trend in cost/ha. Interestingly, the data suggests that average value of production per hectare increases as the size of irrigated land increased. Therefore, the data suggests that an increase in irrigated land leads to a higher profit margin/ha as a result of lower cost/ha and higher gross production values/ha. Hence, when land is a constraint and available irrigable land is less than a quarter of a hectare, investment in motor pump is not economically feasible; therefore, investment in other smallholder irrigation technologies (such as Rope & Washer, treadle pump) could be more advisable. Moreover, cost sharing (co-investment) in motor pump and renting of motor pump are equally important options.

2. The use-life of motor pumps is five years.

3. Since the study is based on data related to smallholder farmers whose landholding size is generally small, we have excluded households whose landholding size is greater than 2.5 hectare. Similarly, because we cannot expect zero production for a household who invest a motor pump, 11 sample households with zero production are considered as outliers and were excluded from the data set.

Figure 5: Investment and production costs and benefits by size of irrigated land (production value/ha/year).

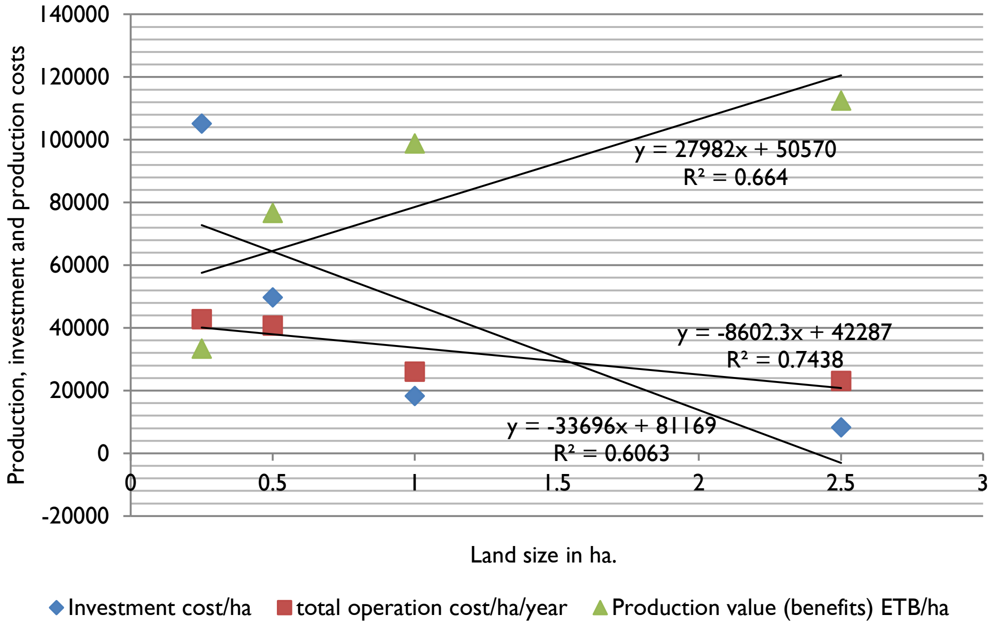


Table 6: Land size and viability of investment in motor pumps for private irrigation

Parameters estimated at average/hectare	Scenario 1: Land size is < 0.25 ha. (N=17)		Scenario 2: land size is >=.25 and <.5 ha. (N=87)		Scenario 3: Land size is >=.5 and <1 ha. (N=144)		Scenario 4: Land size is >=1 and <=2.5 ha. (N=111)	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Investment cost/ha	10,5180	65,791	49,728	33,084	18,277	13,948	8282	10,435
Maintenance and repair cost/ha	8512	13,451	5775	9554	2515	4476	1785	8345
Fuel consumption cost/ha	12,752	10,165	12,330	25,320	4605	5593	4299	10,069
Fertilizer costETB/ha	5296	4543	6859	12,819	5636	8101	5774	8634
Agro-chemicals cost ETB/ha	667	1590	2055	4219	2157	5316	1882	3780
Labour cost ETB/ha	10,239	3295	10,166	9140	8237	5082	7492	7853
Draft-power cost ETB/ha	5051	1893	3035	1727	2422	1473	1421	977
Seed cost ETB/ha	273	486	499	1426	488	749	366	1174
Total operation cost/ha/year	42,790	---	40,719	---	26,060	---	23,019	---
Production value (benefits) ETB/ha	33,336	26,410	76,662	10,3292	98,763	16,2438	11,2445	18,5281
Net cash flow ETB/annum	-9454		35,943		72,703		89,426	
NPV (8.5%)	(-131,276.34)		84,710.14		247,206.91		317,155.63	
NPV (13.9%)	(-120,908.26)		64,938.00		203,616.63		266,476.07	
NPV (25.9%)	(-103,369.68)		35,882.62		137,957.62		180,968.39	
NPV (28%)	(-100,873.11)		32,249.92		129,537.06		170,425.92	
NPV (30%)	(-98,619.90)		29,087.45		122,150.94		161,170.20	
IRR	NA		67%		398%		1080%	

6. Conclusion and discussion

It can be expected that adoption of private irrigation technologies like motor pumps will have an impact on input use and production. This has an implication for policy making and investment decisions. To investigate this issue, we have used the propensity score matching method to quantify the expected impact on input use and production gains from adoption of motor pump-based smallholder irrigation. This method is well suited to the present application since it allows a flexible (nonparametric) description of the effect of motor pump-based smallholder irrigation on input use and production. While the method does not require ad hoc assumptions about the functional form of impacts, it only eliminates selection bias due to observable differences between those with motor pump-based smallholder irrigation and those without it.

We have estimated impacts of motor pump-based smallholder irrigation on input use and production per hectare and found significantly higher input use and production per hectare of irrigated land as compared to similar size of rainfed land. There are statistically significant differences between per hectare input use and production of smallholder farmers with access and without access to motor pump-based irrigation. Based on the three (kernel, nearest neighbour and stratification) matching methods average value of agro-chemical use per hectare on irrigated land was higher than that of rainfed land by about ETB 10,155 to 10,600. Similarly, fertilizer use on irrigated land exceeds that on rainfed land by about 323 and 331 kg/hectare. On the other hand, the overall average production gain due to access to motor pump-based smallholder irrigation ranges between ETB 85,845 and 87,241 per hectare implying that investment in motor pump-based irrigation combined with its effect on input intensification leads to higher production and productivity.

Moreover, the cost-benefit analysis indicated that investment in motor pump-based smallholder irrigation is found to be financially viable at 8.5, 13.9. 25.9, 28 and 30% discount rates. Furthermore, we have simulated net present values using different assumptions of cost and income and were found to be financially viable even if production costs would inflate to the extent of 125% and 35% reduction in annual cash flow.

Furthermore, our results reveal that size of land under irrigation affects the viability of investment in motor pump because cost per unit of output generally decreases with increasing scale of irrigated land. The disaggregated cost-benefit analysis shows that investment is financially viable if irrigated land is at least a quarter of a hectare (0.25 ha). Hence, if land is a constraint and then available irrigated land is less than a quarter of a hectare, investment in other motor pump irrigation technologies (like, Rope & Washer, treadle pump) could be more economical and profitable. Moreover, co-investment in motor pump and motor pump renting systems could be a good option.

However, as initial capital investment and production costs could be prohibitive, resource-poor farmers could be rationed out to benefit from participating in household based smallholder irrigation. Hence, in the absence of equal opportunities, the spread of motor pumps for private irrigation could possibly result in income inequality among better-off and resource-poor farmers because better-off farmers tend to have better access to information and technology than their poorer counterparts. Challenges related to lack of proper agronomic practices and marketing are areas that need to be properly addressed.

Likewise, our cost-benefit analysis shortfalls to capture costs related to environmental costs and risks of negative effect, because the use of individually adopted and less regulated motor pumps can lead to over-abstraction of water, excessive use of fertilizer and agro-chemicals and conflict over water use. Over abstraction of water and excessive use of agro-chemicals may result in land degradation and reduced marginal benefits due to loss of micro nutrients, reduced genetic diversity of crop varieties and high risk of pests and crop diseases that develop resistance to chemical treatments.

When land is a constraint, investment in motor pump may not be economically feasible; therefore, investment in other smallholder irrigation technologies (like Rope & Washer, treadle pump) could be more profitable. Similarly, when land is a constraint, i.e. size of irrigated land holding is less than a quarter of a hectare, it is advisable for smallholder farmers to mobilize their resource to share costs. Then farmers can jointly invest in a motor pump and implement a motor pump renting system.

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