academicJournals

Vol. 6(12), pp. 490-500, December, 2014
DOI: 10.5897/JDAE2014. 0576
Article Number:90D5FBB48609
ISSN 2006-9774

http://www.academicjournals.org/JDAE

Journal of Development and Agricultural Economics

*Full Length Research Paper*

# Economic analysis of factors influencing adoption of motor pumps in Ethiopia

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Received 23 April, 2014; Accepted 7 October, 2014

**The Ethiopian economy depends heavily on smallholder agriculture, and this sector directly affects the country's economic development, food security and poverty alleviation efforts. The adoption of smallholder irrigation technologies as a means to tackle these challenges has become an important policy issue in the development agenda of the country. The lack of access to low-cost irrigation technologies is, however, one of the major bottlenecks to increase smallholder irrigation. This paper examines the factors influencing farmers' decisions to adopt low-cost small motor pumps. The analysis is based on a survey of 800 farm households in four regions of Ethiopia. We use a combination of econometric techniques to find comparable households among adopter and non-adopter sample households. First, we employ a multivariate probit model to check whether a correlation exists between motor pumps and other water lifting technologies (that is, bucket, treadle and electric pumps). A non-parametric matching method is used to identify a counterfactual (control group) among the non-adopter sample households. Finally, a probit model is adopted to model the determinants of farmers' motor pump adoption decisions. Our analysis reveals that gender; age; ownership of oxen; access to extension; access to surface and shallow ground water; social capital and regional differences captured by a regional dummy, all influence farmers' decision of motor pump adoption.**

**Key words:** Smallholder, irrigation technology, propensity score matching, probit.

## INTRODUCTION

Investment in irrigation, particularly in small-scale and household level irrigation, has been identified as a core strategy in Ethiopia to reduce the strength of the link between agricultural production from rainfall and climate risk to improve crop production (Hagos et al., 2009). Irrigation also requires the use of modern inputs (such as, fertilizers and improved seeds), which further enhance agricultural productivity (World Bank, 2006; MoFED, 2006; Diao et al., 2010; Gebregziabher and Holden, 2011). To alleviate poverty, the financial gains from

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irrigation need to be geographically scaled out to widen the access and participation of many poor farmers. Small-scale private irrigation using small pumps has a greater chance to reach and involve many smallholders than command and scheme level irrigation approaches (Rydzewski, 1990; Fan and Hazell, 2001; Shitundu and Luvanga, 1998). Experience from Sub-Saharan Africa shows that investments in scheme level irrigation in the 1970s and 1980s did not meet targets for food production because economic problems, such as high capital investment and management costs, impeded the performance of large scale irrigation (Adams, 1991). Similarly, Lam (1996) shows that in Asia, small-scale schemes perform better than large-scale systems partly due to constraints by government bureaucracy on the latter and has promoted a shift to small-scale irrigation. Furthermore, D'Souza and Ikerd (1996) argued that from a sustainability perspective, small-scale farms are more effective and competitive compared with large-scale farms. Likewise, Ofosu et al. (2010) documented that in the Volta basin, irrigation technologies are frequently better managed by farmers and consequently result in higher productivity and good profit margins. Ofosu et al. (2010) also suggest that as compared to scheme level irrigation, small-scale irrigation technologies are more profitable and financially sustainable than large-scale irrigation, because they provide income opportunities to the wider society in terms of employment and participation of women. Moreover, experience from India suggests that given the right conditions, the use of small pumps and other micro-irrigation technologies commonly used in water scarce areas is an efficient use of irrigation water that can improve the productivity of water; generate income and financial benefits; and enhance food security of farm households (IWMI, 2006).

Likewise, D'Souza and Ikerd (1996) and Lam (1996) argue that smallholder and household level irrigation technology is more likely to bring higher returns per hectare than large-scale irrigation schemes. However, FAO (2005) has documented that only 13% of the irrigation potential of Sub-Saharan Africa is currently developed, largely due to past experience in irrigation development in the region emphasizing large-scale irrigation, which in most cases is constrained by high cost and management complexity. In the 1980s and 1990s, emphasis began to shift to smallholder irrigation using simple technologies, such as small and inexpensive pumps (Abric et al., 2011; Kay, 2001). For example Perry (1997) recommended low-cost manual and/or mechanized irrigation technologies as promising interventions in Sub-Saharan Africa while de Lange (1997) concluded that small-scale irrigation developed from farmers' initiative in Sub-Saharan Africa is more successful than government initiated large-scale irrigation.

Ethiopia has substantial surface and groundwater potential (Makombe et al., 2007; Awulachew, 2010; Awulachew et al., 2006; Cherre, 2006), although to date, farmers have not accessed this at a large enough scale to produce enough food to remove issues of regional poverty and food insecurity. Whilst irrigation has the potential to increase cereal yields by up to 40% (Diao et al., 2010), agricultural producers in Ethiopia have used only about 5 to 6% of the country's irrigation potential (Awulachew et al., 2007), mainly through large- and small-scale community irrigation schemes.

For the purpose of this paper, 'small' motor pumps are between 1 to 10 horsepower and costs between US$200 to US$1,000. Smallholder farmers usually use their own financing mechanisms to purchase these pumps to irrigate less than 5 ha of land to produce cash crops. The pumps are owned and managed individually or by small informal groups of farmers to pump water from rivers, lakes, reservoirs and shallow aquifer.

Data on private smallholder irrigation and the use of small pumps are not readily available and national estimates vary considerably. For example, Kay (2001) report that Ethiopia's potential irrigated area is approximately 670,000 ha, of which in 1992 about 82,000 ha and 5,000 ha were irrigated using large-scale and small-scale irrigation, respectively. More recently, Awulachew et al., (2005) report that the aggregated maximum irrigation potential in Ethiopia (including small, medium and large-scale) is about 3.7 million ha, of which only about 197,000 ha, or 5.3%, is irrigated. Furthermore, Santini et al. (2011) suggest that the potential for small private motor pump irrigation in Ethiopia is between 1.4 and 2.8 million ha, from which about 9 to 18 million people could benefit. However, except for some indicative government statistics, information on the current status of motor pump adoption in Ethiopia is largely unavailable.

The premise of this paper is that smallholder farmers can play a significant role in Ethiopia's irrigation development provided they have access to appropriate low-cost water lifting technologies. Ofosu et al. (2010) defined irrigation technology as "a method and techniques for diverting and/or pumping, storing, transporting and distributing ground, surface and rainwater to agricultural crops", and Perry (1997) has characterized motor pumps as "low-cost irrigation technologies". Based on unpublished reports in the regional bureaus of water resources, motorized small pumps are among the emerging private irrigation technologies in rural Ethiopia. The spread of small pumps occurs through the regional bureaus of water resources mainly distributed on credit and through direct purchase with farmers' own resources. According to Ethiopian government statistics (Ethiopian Revenue and Customs Authority), about 800,000 motor pumps have been imported between August 2004 and December 2010, while unpublished reports from the regions show that at the end of 2009, the regional bureaus of water resources have distributed 19,338 pumps in Oromia, 20,916 in

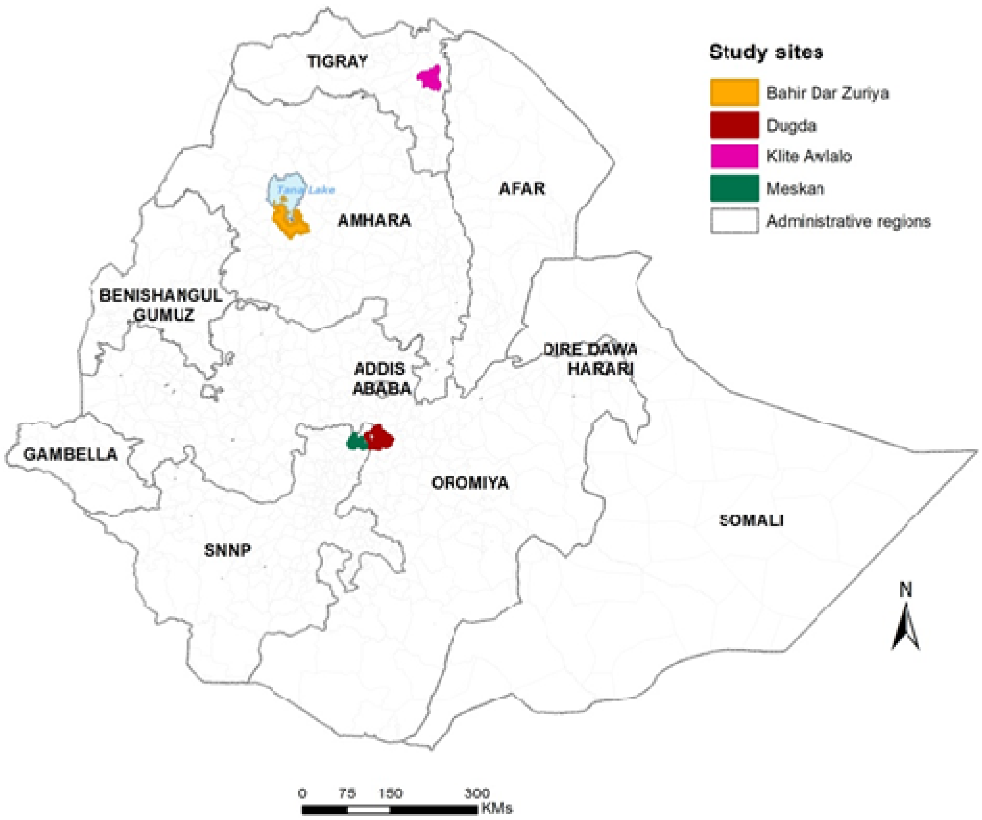


**Figure 1.** Study areas of Region and Districts

Amhara, and 18,348 in Tigray. Given that only 5 to 6% of Ethiopia's irrigation potential is being used, it is likely that private small-scale irrigation using pumps would benefit smallholder farmers. However, information on factors that influence the adoption of smallholder water lifting irrigation technologies is scant. The main objective of this paper is, therefore, to study the factors that affect smallholder farmers' adoption of small motor pumps in rural Ethiopia. The paper aims to contribute to the growing literature on adoption of smallholder irrigation and informing policy making in a country that has put irrigation at the heart of its agricultural development strategy.

## METHODOLOGY

### Data collection

In this study, we utilise data from a household survey collected during January-April, 2010 from four districts of the four main regions (Amhara, Oromia, SNNP and Tigray) of Ethiopia (Figure 1). Primary data were collected from 800 randomly selected farm households, using a multi-stage stratified random sampling method. In the first stage, we used information from the regional bureaus of agriculture to identify *wereda* (Districts) with a high concentration of smallholder irrigation technologies, such as buckets, treadle pumps, motorized pumps, and electric pumps. In the second stage, information from agricultural offices of the selected *weredas* was used to select *Kebeles* (communities) that have high adoption rates of these technologies. In the third stage, a list of farm households in the selected communities was used to disaggregate them into adopter and non-adopter households. Finally, we used a proportional random sampling technique to select our sample households. Of the total sample households, 266 were classified as adopters of motor pumps (Table 1).

### Empirical analysis

This paper uses both descriptive and econometric analysis techniques. We assume that the production system represents a multi-crop agricultural production unit where land holding is fixed, but the allocation of land into crop type and irrigation is possibly endogenous. The adoption decision of irrigation technology is a discrete outcome where the farmer faces a dichotomous decision to adopt or not to adopt a motor pump. In our context, motor pump adopters are those farmers who were using motor pumps (petrol or diesel, rented or purchased) during the data collection to irrigate all or part of their land, while the rest are non-adopters.

Among the sample households, some of them have adopted a combination of technologies, such as motor pumps, bucket, treadle pumps, electric pumps and other water lifting technologies. These households may have adopted these technologies as substitutes or complements as they may have faced interdependent/correlated choices of technologies in their adoption decisions. Moyo and Veeman (2004); Marenya and Barrett (2007); Nhemachena and Hassan (2007); Yu et al. (2008) and Kassie et al. (2009) argue that farmers usually consider a set of possible technologies and try to

**Table 1.** Sample households and type of technologies by region.

| Type of technology | Region | | | | Total |
|---|---|---|---|---|---|
| | Amhara | Oromia | SNNPR | Tigray | |
| Purely rain-fed cultivators (Non-adopters) | 115 | 118 | 120 | 146 | 499 |
| Bucket | 0 | 0 | 5 | 0 | 5 |
| Treadle pump | 3 | 1 | 5 | 0 | 9 |
| Motor (petrol/diesel) pump[a] | 66 | 68 | 73 | 59 | 266 |
| Electric pump | 0 | 21 | 0 | 0 | 21 |
| Other type of technology | 21 | 6 | 0 | 0 | 27 |
| Total number of sample household[b] | 200 | 200 | 200 | 200 | 800 |

**a,** Other type of technology includes rope and washer, wind mill, solar pumps, etc; **b,** the sum exceeds the total sample size, because some households have adopted more than one technology

**Table 2.** Correlation coefficients between irrigation technologies.

| Irrigation technology | Motor pump | Bucket | Treadle pump |
|---|---|---|---|
| Bucket | $\rho_{21}$ 0.436***(0.072) | | |
| Treadle pump | $\rho_{31}$ 0.298***(0.092) | $\rho_{32}$ 0.193(0.270) | |
| Electric pump | $\rho_{41}$ 0.222* (0.119) | $\rho_{42}$ 0.198(0.184) | $\rho_{43}$ -0.024(0.148) |

$\chi^2$ (6) = 27.483; probability > $\chi^2$ = 0.000.

**Table 3.** Sample households that adopt bucket, treadle pump, electric pump and other irrigation technologies by region.

| Technology | Region | | | | Total |
|---|---|---|---|---|---|
| | Amhara | Oromia | SNNPR | Tigray | |
| Bucket | 7(7) | 14(13) | 9(3) | 2(2) | 32(25) |
| Treadle pump | 5(5) | 7(4) | 9(7) | 0 | 21(16) |
| Electric pump | 1(1) | 23(14) | 0(0) | 0(0) | 24(15) |
| Other | 21(2) | 7(3) | 0(0) | 0(0) | 28(5) |
| Total | 34(15) | 51(34) | 19(10) | 2(2) | 105(61) |

1) Figures in parenthesis shows number households who also adopt motor pump; 2) Other types of technology includes rope and washer, wind mill, solar pumps, etc.

adopt a mix of technologies they assume can maximize their expected utility. While the adoption decision is inherently multivariate, recent studies on technology adoption (Tsefay, 2011; Nata and Bheemalingeswara, 2010; Deressa et al., 2009; Amha, 2006) assume a single technology without addressing the correlation and interdependence between the technologies. When a multitude of technology option exists, like in our case, a household may have equal opportunity, given their financing options, to choose from the set of technologies. In this situation farmers may well consider some combination of technologies as complementarity or competing. Hence, failure to capture such correlation/interdependence is likely to mask the reality that decision-makers face in their adoption decision. Consequently the results will be potentially biased and inefficient leading to underestimate or overestimate the influences of various factors in the adoption decisions.

Therefore, to identify the possible correlation that may exist between the irrigation technologies, we adopt and estimate a multivariate probit (MVP) model, which establishes a positive correlation between motor pumps and the other three (bucket, treadle pump and electric pump) irrigation technologies. This implies that a household's decision to adopt one of these technologies is likely to influence motor pump adoption (Table 2). A likelihood ratio test [$\chi$ 2 (6) = 27.48 and probability > $\chi$ 2 = 0.000] indicates significant joint correlations between the irrigation technologies under discussion implying the error term in the adoption of motor pumps is not independent of the other irrigation technologies. Both the correlation and likelihood ratio test justify that the estimation of the multivariate as opposed to separate univariate model is appropriate.

Given the very small number of bucket, treadle pump and electric pump adopters (Table 3); it may not be possible to generate illustrative regression results in relation to these technologies. Moreover, information on the adoption of bucket, treadle pump and electric pump is missing from the dataset of some study areas. For example, the data that we have from Tigray is only on motor pumps. Although, unless due to problems attributed to data collection, this does not mean bucket and treadle pumps are not used in the region. Furthermore, electric pumps are only an option in Oromia, where there is a large-scale electric pumped scheme at Lake Zeway. In general, due to practical reasons, our dataset on adoption of irrigation technologies is dominated by motor pumps, hence, even though small in number, treating the households that adopt bucket, treadle pump or electric pump as non-adopters in the analysis is likely to result in data contamination and inefficient results. To control for this potential problem, we omitted the 94 sample households who adopted irrigation technologies other than motor pumps. This left a sample of 706 (212 motor pump adopters and 494 are purely non-adopters) households. The reason the number of omitted sample households is less than the total in Table 3 (that is, 105) is because 11 households adopted more than two technologies and were double counted in the summary.

Since the adoption of motor pumps is not random, a selection bias is still a potential problem, as the adoption of motor pumps can be related to a number of factors (such as: unobserved household characteristics; proximity to water source; access to information and others). In addition, the remaining non-adopter sample households may not properly approximate the adopting sample households to serve as a counterfactual (control group). Hence, comparing adopters with the non-adopters without matching may still result in biased and inconsistent results.

In controlling the potential problem of selection bias, a propensity score matching method was used to identify 'real' comparable (counterfactual) sample households (Cobb-Clark and Crossley, 2003; Heckman et al., 1998; Ravallion, 2005). The basic assumption of using propensity score matching is that the matched non-adopter sample households approximate the adopters if they had not adopted. Given the control variables, this implies that the counterfactual outcome for the adopter group is the same as the observed outcomes for the non-adopting group (Heckman et al., 1998). In some cases, however, matching of adopting and non-adopting households based on observable characteristics may not be feasible, especially when the dimension of control variables is large. To overcome this problem, we employ the propensity score, $p(X)$ method that summarizes the multi-dimensional variables (Rosenbaum and Rubin, 1985). Propensity score is a conditional probability that household $i$ has adopted a motor pump given the conditioning variables, written as:

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

Where $p$ (the propensity score) represents the probability of motor pump adoption given unobservable household characteristics $(x)$ and $MP$ ($motor \quad pump$) is equal to 1 for adopters and 0 for non-adopters. For the propensity score to be valid, the balancing properties need to be satisfied, implying that households with the same probability of adoption will be placed in the treated (adopter) and untreated (non-adopter) samples in equal proportions. Once the propensity score (pscore) is estimated, the data is split into equally spaced pscore intervals, implying that within each of these intervals, the mean pscore of each conditioning variable is equal for the adopter and non-adopter (control) households, known as the balancing property (Cobb-Clark and Crossley, 2003).

In line with this, the adopter and non-adopter households were matched based on observable characteristics (such as, household head's gender, off-farm participation, family size, access to credit, access to extension service, social capital in the form of household's membership in farmer associations, household's leadership role, farm size and tenure arrangement). Finaly, we found that out of the 494 non-adopter sample households, 420 of them have satisfied the balancing property implying that they can be used as counterfactuals (control group) in the adoption analysis.

Concern about endogeneity is quite high in the adoption decision, because only households with access to water sources might consider adopting motor pumps. In an effort to account for such structural issue, we used WU-Hausman for the endogeneity test and found insignificant *F-test* coefficients [*F (1,669) =2.330 and P=0.128*], implying that the suspected variable (that is, access to water sources) is not endogenous in the adoption equation.

After identifying counterfactuals (control households) in the adoption analysis and validating that the suspected variable is not endogenous, we employed a binary outcome (probit) adoption model to estimate factors that influence households' adoption of motor pumps using the matched sample households. The probit model assumes that while we only observe the values of 0 for non-adopters and 1 for adopters for the outcome variable $(Y)$, there is a latent unobserved, continuous variable that determines the value of $(y^*)$. The probit model is specified as:

$$y^* = \alpha + \Sigma X_i \beta + \varepsilon, \varepsilon \approx N(0,1) \tag{2}$$
$$If \;\; y^* > 0, \quad Y = 1$$
$$if \;\; y^* \leq 0, \quad Y = 0$$

Where $y^*$ is the outcome variable (adoption of motor pump) equal to 1 if household $i$ adopted motor pump and 0 otherwise. $X_i$ is a vector of values for the $ith$ observation, $\beta$ is a vector of parameters to be estimated and $\varepsilon_i$ is the error term.

**Explanation of variables and hypotheses**

Following the adoption literature (e.g., Kassie et al., 2012; Pender and Gebremedhin, 2007; Marenya and Barrett, 2007; Bandiera and Rasul, 2006; Lee, 2005), the explanatory variables included in our regression analysis and their hypothesized effect on adoption of motor pumps are discussed below.

***Human capital***

Household characteristics, such as education, age, family size and gender may affect a households' decision to adopt irrigation technologies. Households with more educated members may have greater access to non-farm income and are able to finance the purchase of irrigation technologies. Furthermore, better educated farmers are likely to be more informed about the benefits of modern technologies and may have a greater ability to translate information and analyse the importance of technologies (Pender and Gebremedhin, 2007; Kassie et al., 2011). On the other hand, educated farmers are able to earn higher returns on their labour and capital if they are used in other activities (Pender and Gebremedhin, 2007).

Similarly, age may capture farming experience and exposure to production technologies implying an ability to respond to unforeseen events/shocks. It may also imply that older farmers have a life time accumulation of physical and social capital suggesting greater respect in their community. On the other hand, age can be associated with loss of energy, short-planning horizons and being risk averse. Thus, the impact of age on technology adoption is ambiguous prior to being empirically tested. It has been argued that women have less access to crucial farm resources (land, labour, and cash) and are generally discriminated in terms of access to external inputs and information (De Groote and N'Golo, 1998; Quisumbing et al., 1995). In Sub-Saharan Africa, there are gender specific constraints, such as women's poorer access to education, land and production assets (Ndiritu et al., 2011). It is obvious that these constraints have direct effects on technology adoption including irrigation technologies where women are usually less likely to adopt. In this paper, gender is specified as dummy variable equal to 1 for male and 0 for female.

#### *Access to market*

Access to markets can influence farmers' decision making in various ways, such as availability of technology, the use of output and input markets, and access to information and support organizations, for example, credit institutions (Jansen et al., 2006; Wollni et al., 2010; Pender and Gebremedhin, 2007). It can also increase the amount of labour and/or capital intensity by rising output to input price ratios. The hypothesis here is that the further away a village or farming household is from a market, the less likely it is to adopt new technology.

#### *Physical capital*

This variable is represented by livestock ownership and farm size as proxies of household wealth. Wealthier households are better able to bear risk associated with the adoption of motor pumps and to finance purchase of motor pumps. Furthermore, as mixed farming (crop-livestock farming) production system is common practice in the Ethiopian context, livestock may serve as source of manure and draft power. In such a situation irrigated crop production may generate fodder for livestock; hence, the linkage between crop and livestock production systems may encourage adoption of irrigation technologies.

#### *Off-farm participation*

Economic incentives play an important role in the adoption of technologies, although their effects may be complex and subtle (Lee, 2005). Household access to alternative sources of employment and return from such activities are likely to influence the adoption of motor pumps, but in different directions. For example, households that have alternative sources of income may have greater capacity to pay and adopt the technologies. On the other hand, off-farm activities may divert time and labour from agricultural activities, reducing investments in irrigation technologies and the availability of labour that can be used in irrigation. In this paper, off-farm participation is defined as equal to 1, if the household has participated in off-farm activity and 0 otherwise. The hypothesized effect of off-farm participation on the adoption of irrigation technologies is, therefore, ambiguous.

#### *Land tenure*

A number of studies have demonstrated that security of land ownership has a substantial effect on the agricultural performance of farmers (Besley, 1995; Kassie and Holden, 2007; Deininger et al., 2009). In this paper, tenure security is indicated by land tenure (1=owned by the farmer, 0=otherwise) and we assume that households who produce on their own land have better tenure security and are more likely to invest in irrigation technologies.

#### *Social networks*

This represents a combination of variables, such as membership in farmer groups or associations and number of traders that a respondent knows as a proxy of market network. Isham (2007) and Bandiera and Rasul (2006) suggest the positive effects of social networks and personal relationships on technology adoption. With scarce or inadequate information and imperfect market, a social network allows and facilitates the exchange of information, enables farmers to access inputs and overcome credit constraints. Social networks also reduce transaction costs and increase farmers' bargaining power, helping farmers to earn higher returns when marketing their products that can also affect technology adoption (Wollni et al., 2010; Lee, 2005). Farmers who do not have contacts with extension agents may still find out about new technologies from their networks, as they share information and learn from each other. Membership in farmers' groups or associations is therefore hypothesized to be positively associated with adoption of motor pumps.

#### *Biophysical characteristics*

Agricultural production in Sub-Saharan Africa is characterized by wide variability of agro-ecological and biophysical factors. We asked our respondents whether they have year round access to surface and shallow groundwater. Two dummy variables (access to ground and surface water) are included in the regression. The assumption is that those households have access to surface and/or ground water are more likely but not certain to adopt motor pumps. Moreover, other biophysical (e.g., rainfall, topography, soil type) and socioeconomic characteristics (e.g., population, production risk) may influence the adoption of water lifting technologies. For example, in the Ethiopian highlands, topography follows a gradient from flat lowlands to mountainous area (Pfeifer et al., 2012). The same report indicates that most of the western Ethiopian highlands are dominated by Nitisols that are stable and relatively less prone to erosion, while the eastern part and highland plateau of the Blue Nile Basin are dominated by leptosols and vertisols, respectively. Leptosols are relatively shallow and prone to erosion while vertisols are low drainage heavy clay soils, implying that topographical and soil characteristics may influence the recharge and availability of groundwater, suitability of irrigation technologies. However, due to lack of site specific biophysical and socio-economic data, we use region dummies to capture unobserved site specific biophysical and socioeconomic differences.

## RESULTS

### Descriptive results

The definition and summary statistics of variables used in the analysis are presented in Table 4. About 34% of the total matched sample households have adopted motor pumps. In many parts of the Sub-Saharan African countries, male farmers dominate the farming system and technology adoption, which our data also show. Male headed households constitute about 92% of the total sample households and about 97 and 89% of the adopter and non-adopter sample households, respectively.

**Table 4.** Definition of variables and descriptive statistic.

| Dependent variable | | | Mean | | SD | | |
|---|---|---|---|---|---|---|---|
| Adoption of Motor pump (1 = yes, 0 = no) | | | 0.335 | | 0.473 | | T-test/significance of difference |
| Independent variables | Total sample households | | Non-adopters | | Adopters | | |
| | Mean | SD | Mean | SD | Mean | SD | |
| Household head's gender (1 = male, 0 = female) | 0.916 | 0.277 | 0.890 | 0.313 | 0.967 | 0.179 | 0.001*** |
| Household head age (years) | 44.323 | 14.024 | 45.464 | 14.043 | 42.061 | 13.739 | 0.004*** |
| Ownership of oxen in tropical units (TLU) | 1.212 | 1.116 | 1.069 | 1.049 | 1.495 | 1.190 | 0.000*** |
| Ownership of non-oxen livestock in tropical units (TLU) | 2.747 | 3.006 | 2.451 | 2.827 | 3.333 | 3.261 | 0.000*** |
| Adult household member (number) | 3.036 | 1.564 | 2.983 | 1.453 | 3.142 | 1.763 | 0.230 |
| Educated household member (number) | 2.723 | 2.096 | 2.590 | 2.034 | 2.986 | 2.195 | 0.025** |
| Access to extension (1 = yes, 0 = otherwise) | 0.560 | 0.497 | 0.524 | 0.500 | 0.632 | 0.483 | 0.010** |
| Access to credit (1 = yes, 0 = otherwise) | 0.237 | 0.426 | 0.224 | 0.417 | 0.264 | 0.442 | 0.261 |
| Household has market network (1 = yes, 0 = no) | 0.071 | 0.257 | 0.057 | 0.232 | 0.099 | 0.299 | 0.053* |
| Household membership in farmer association (1 = yes, 0 = otherwise) | 0.650 | 0.477 | 0.626 | 0.484 | 0.698 | 0.460 | 0.074* |
| Farm size (ha) | 2.323 | 1.540 | 2.184 | 1.397 | 2.600 | 1.761 | 0.001*** |
| Land tenure (1 = owned, 0 = leased in) | 0.992 | 0.089 | 0.990 | 0.097 | 0.995 | 0.069 | 0.520 |
| Availability of surface water (1 = yes, 0=otherwise) | 0.381 | 0.486 | 0.236 | 0.425 | 0.670 | 0.471 | 0.000*** |
| Availability of ground water (1 = yes, 0=otherwise) | 0.166 | 0.373 | 0.100 | 0.300 | 0.297 | 0.458 | 0.000*** |
| Region dummies | | | | | | | |
| Amhara (1 = yes, 0 = otherwise) | 0.245 | | 0.245 | | 0.245 | | |
| Oromia (1 = yes, 0 = otherwise) | 0.223 | | 0.240 | | 0.189 | | |
| SNNPR (1 = yes, 0 = otherwise) | 0.264 | | 0.248 | | 0.297 | | |
| Tigray (1 = yes, 0 = otherwise) | 0.267 | | 0.267 | | 0.269 | | |

The summary statistics also show that younger farmers are more likely to adopt motor pumps as compared to older farmers. This is consistent with Ahmed et al. (2002) that older farmers are risk averse and usually stick to traditional farming systems. Physical assets (proxied by ownership of livestock) are significantly different from those who own more physical assets being in a better position to finance the purchase of new technologies, especially when credit is a constraint. Farm size as a proxy of physical assets is also significantly higher for adopters as compared to non-adopters. Education and access to extension are positively related to adoption. Finally, the summary statistics reveal that those who have a positive perception about the availability of surface and shallow ground water are more likely to adopt motor pumps. One may argue that these households are located in more favorable settings, so that they have better access to a source of irrigation water leading to a high adoption rate. However, the fact that we use matched sample households in the analysis possibly invalidates such an argument.

Assessment of market prices of motor pumps is an integral part of this study. A motor pump of 3.5 HP[*] that can irrigate about 2 ha costs about US$1,087 (equivalent to 12,500 Ethiopian Birr). Data from the revenue and customs authority of Ethiopia also show that the average cost of a motor pump is estimated at US$565 of which government taxes account for about 37% of the costs[†]. Furthermore, since motor pumps do not stand alone, the cost of accessories and other irrigation infrastructure are important in the motor pump adoption process. Information from our survey suggests that the average cost of motor pump accessories, maintenance and construction of wells is in the order of US$165 (Table 5), which makes the investment more expensive.

## Results from the regression analysis

Here, we discuss the results obtained from the probit model. Table 6 presents regression results of the adoption (probit) model. The data suggest that household, socioeconomic and biophysical characteristics all affect households' motor pump adoption decisions. For example, male headed households are more likely to adopt motor pumps as compared to female headed households indicating that female headed households are less likely to benefit from motor pump adoption than male headed households.

The negative association between adoption of motor pumps and age imply that older farmers are less likely to adopt as compared to younger farmers. This can be associated with short planning and risk averse behavior

[*] HP represents horsepower.

[†] The Ethiopian Birr was devalued by about 20% in September 2010, significantly increasing the price of imports, including motor pumps, so that the current price of pumps is likely much higher.

**Table 5.** Average cost and tax rate of imported water pumps.

| Cost Component | Average |
|---|---|
| Average CIF value of water pump (Birr) | 4668 |
| Average tax per unit of water pump (Birr) | 1832 |
| Average purchase price/water pump (CIF+Tax) (Birr) | 6500 |
| Tax rate | 36% |

Source: Summarized Based on Data from Ethiopian Customs and Revenue Authority

**Table 6.** Regression results of the adoption (Probit) model.

| Variable description | Coefficient | Robust Std. Err. |
|---|---|---|
| Household head's gender (1 = male, 0 = female) | 0.664*** | 0.249 |
| Household head age (years) | -0.015** | 0.006 |
| Ownership of oxen in tropical units (TLU) | 0.145* | 0.080 |
| Ownership of non-oxen livestock in tropical units (TLU) | 0.008 | 0.031 |
| Adult household member (number) | 0.051 | 0.057 |
| Educated household member (number) | -0.024 | 0.043 |
| Access to extension (1 = yes, 0 = otherwise) | 0.319** | 0.140 |
| Access to credit (1 = yes, 0 = otherwise) | -0.112 | 0.187 |
| Household has market network (1 = yes, 0 = no) | 0.365 | 0.262 |
| Household membership in farmer association (1 = yes, 0 = otherwise) | 0.292* | 0.151 |
| Farm size (ha.) | 0.067 | 0.045 |
| Land tenure (1 = owned, 0 = leased in) | *0.614* | *0.484* |
| Availability of surface water (1 = yes, 0 = otherwise) | *1.767**** | *0.169* |
| Availability of ground water (1 = yes, 0 = otherwise) | 0.936*** | 0.183 |
| | | |
| Region dummies (control region is Tigray) | | |
| Amhara (1 = yes, 0 = otherwise) | -1.391*** | 0.278 |
| Oromia (1 = yes, 0 = otherwise) | -0.918*** | 0.272 |
| SNNPR (1 = yes, 0 = otherwise) | -0.641*** | 0.240 |
| Constant | -2.103*** | 0.591 |
| Number of observation | 632 | |
| Log pseudo likelihood | -278.493 | |
| Wald $\chi^2(17)$ | 155.190 | |
| Prob > chi2 | 0.000 | |
| Pseudo $R^2$ | 0.31 | |

*, **, *** are levels of significance at 10, 5 and 1%, respectively. Figures in parentheses are robust standard errors.

of older farmers and supports the findings of previous research (Kassie et al., 2012; He et al., 2007). In terms of wealth factors, ownership of oxen is positively related to the adoption of motor pumps, suggesting that wealthier farmers are more likely to take risk as compared to poor farmers. This is consistent with the findings of research carried out in Egypt (Mourshed, 1995), which found that risk causes anxiety towards new innovations and unfamiliar techniques can produce uncertain yields. As a result, farmers with limited incomes or assets are reluctant to adopt unproven/unfamiliar technologies.

Access to extension is also positively related with the adoption of motor pumps as farmers' awareness and skills to efficiently use of the technology is expected to increase. For example, Mourshed (1995) documents that Egyptian small desert farmers adopt drip irrigation after witnessing the success of nearby large farmers. This may hint to the importance of strengthening extension service. This can be achieved, for example, by organizing formal and informal experience-sharing tours and farm 'field-days' to learn from nearby better performing model farmers and from that scaling up best practices in technology adoption.

As expected, farmers' perception about the availability of surface and shallow ground water has both a positive and significant effect (both at 1% level of significance) on the probability of motor pump adoption. This suggests that scientific evidence about the potential of ground/surface availability to increase farmers' confidence and willingness to adopt irrigation technologies is an important factor. Furthermore, the adoption of motor pumps varies by region. This variation is most likely due to region specific socio-economic and biophysical characteristics differences, such as rainfall, topography, erosion, and soil and water conservation. The negative coefficients for Amhara, Oromia and SNNPR dummies for adoption of motor pumps suggest a lower probability of adoption of motor pumps in these regions as compared in Tigray. This probably reflects the effect of unobservable spatial differences (such as rainfall, land degradation and land fertility) as well as the difference in soil/water conservation and watershed management activities between the regions. For example, since the 1970s, there have been intensive and relatively successful soil/water conservation and watershed management activities in Tigray (Woldearegay, 2012), which has led to increased infiltration and groundwater recharge and in turn an increased adoption of household level private irrigation technologies. On the other hand, previous research (Pender et al., 2006; Aiayi, 2007; Kassie et al., 2012) stated that several biophysical and socioeconomic factors have been identified as limiting factors for increasing food production for most smallholder farmers in Sub-Saharan Africa. Furthermore, Kassie et al. (2012) argues that such unfavourable biophysical factors are likely to encourage farmers to adopt production enhancing technologies as a coping mechanism.

## DISCUSSION AND CONCLUSIONS

In Ethiopia, agriculture is the main sector that substantially influences economic development, food security and poverty alleviation. The sector is dominated by smallholder farmers. However, low and high variability of rainfall combined with low levels of technology adoption characterize the performance of agriculture. As a result, in a country where there is substantial surface and groundwater potential, farmers are unable to access it to produce enough food. Moreover, information on private smallholder irrigation and the use of smallholder irrigation technologies is not readily available and lacks consistency. Recent studies indicate that the potential for small private motor pump irrigation in Ethiopia is in the order of 1.4 up to 2.8 million ha (Santini et al., 2011 ) and can benefit between 9 to 18 million smallholder farmers.

Regression results show that there is heterogeneity with regard to the factors that influence the adoption of motor pumps. It underscores the importance of gender; age; ownership of oxen; access to extension; social capital in the form of farmers' membership in farmer associations; access to surface and shallow ground water and region specific socio-economic and biophysical differences. There is a need for more research to identify site specific socio-economic and biophysical factors in the adoption and dissemination of smallholder water lifting technologies and then targeting these technologies where they perform well.

Our results also suggests that the probability of motor pump adoption increases with farmers' participation in farmer associations implying local rural institutions can assist farmers in providing information, credit, experience sharing and market outlets. The positive effect of access to extension on motor pump adoption emphasizes the need to improve the extension system. Finally the adoption of motor pumps is influenced by farmers' gender, age and wealth. The policy implication of this result is that targeting women's groups to address their constraints to actively participate in the adoption of irrigation technologies and rural economic activities in general can have a significant impact on the adoption of smallholder water lifting irrigation technologies and improved livelihoods.

Beyond the regression results, our survey data also show that the cost of motor pumps is high and prices continue to increase. Government taxes account for about 37% of the prices. The cost of accessories and irrigation infrastructures are also quite high for resource poor farmers. The supply of agricultural inputs, fuel and maintenance service is a critical problem. The output market is highly fragmented where informal brokers have un-proportional power to set market prices, usually against the interest of farmers. Frequent mechanical breakdowns are widespread due to farmers' lack of skills, while the supply of spare parts and maintenance services are lacking in the rural areas. Knowledge about environmental risk of motor pump use (that is, risk of groundwater depletion) is seldom. Hence, we suggest that further studies need to understand welfare and environmental implication of motor pump adoption and policies to support the dissemination of motor pumps for smallholder irrigation as a poverty reduction strategy.

## Conflict of Interest

The authors have not declared any conflict of interest.

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