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Smallholder Farmers' Willingness to Invest in Irrigation Schemes in Dedza, Malawi

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Abstract As governments look to alleviate their budgets and encourage local management of natural resources, interest in irrigation management transfer (IMT) has grown. IMT is the handover of control and ownership of an irrigation system from a public sector entity to a private sector organization. With Malawi's ineffective irrigation systems, burgeoning population density, and strained water resources, IMT is an attractive option for policy makers. Planners of upcoming IMT projects must thoroughly investigate the willingness of farmers to invest in irrigation schemes, and use the findings to create realistic expectations for all IMT stakeholders. This paper analyzes the willingness of smallholder farmers to invest capital and unpaid labor in the construction, maintenance, and management of four types of irrigation schemes. A high willingness to invest in hypothetical irrigation schemes, in some cases, is explained by a greater household labor endowment, a higher education level, a higher elevation, a stronger social network, and the perception that irrigation is important to yield. These findings could be used as a basis for IMT budget estimates, but are not a substitute for in-depth research in particular areas where IMT is planned. Policy makers are encouraged to tailor IMT projects to individual households' abilities to invest capital, unpaid labor, or a combination of the two.

Keywords: *irrigation management transfer, willingness to pay, water resource investment, unpaid labor, Malawi*

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1. Introduction

Over the past two decades, a trend of devolution of natural resource control from government agencies to user groups has occurred. Within the devolution trend are different types of programs with varying levels of handover, including: participatory management, wherein user involvement is encouraged as a complement to government control; joint- or co-management, wherein users handle certain responsibilities in conjunction with the state; and community-based resource management, wherein there is a total transfer of control [8]. Along this spectrum is Irrigation Management Transfer (IMT), which is the transfer of ownership and management of irrigation schemes from the public to the private sector [6], for example in Malawi from the Ministry of Agriculture, Irrigation and Water Development to a local water users' association.IMT usually begins with a minor involvement of water users in a government-run scheme with the aim of a gradual complete handover of control of the irrigation scheme to the farming community.

According to Meinzen-Dick and Knox [8], devolution policies, including IMT, generally have three objectives in common. The first objective is to more effectively manage natural resources and enforce resource use rules. Micromanaging natural resources is not easily done by national governments; local common property regimes hold the comparative advantage in knowledge of their own area and have stronger incentives than outsiders to safeguard the resources that provide their livelihood. The second objective is to increase democratization and thereby empower local people. The third objective, which is arguably most important to policy makers, is to alleviate financial strain on the national government. The costs associated with employing and transporting government staff to monitor natural resources of vast and remote areas are monument a land can be reduced by passing the responsibility to local residents. If governments do not come to this budgetary conclusion on their own, they are often pushed to do so by donor organizations [8].

With the acceleration of population growth and repeated droughts over the past few decades, Malawi is turning towards irrigation to increase incomes and improve food security [5,9]. Data on Malawi's total irrigated land area is outdated, but shows a pattern of growth. There were an estimated 56,390 hectares of land equipped for irrigation in 2002, which was a significant increase from 24,048 hectares in 1994 [4] To alleviate the budgetary impact of this irrigation surge, the government has sought to transfer the management of state-owned schemes to farmer organizations. In addition to significant national budget relief, user participation in irrigation management is expected to encourage sustainable operations by inducing a sense of ownership and responsibility among farmers.IMT programs face a multitude of challenges and have not been entirely successful in Malawi thus far [11].

This study seeks to provide insight into smallholder farmers' preferences for different irrigation technologies, and the extent to which they are willing to invest in communally-owned irrigation schemes, as well as the traits and conditions that drive that willingness. The findings are intended for use by policy makers to improve budget estimates for irrigation projects and IMT programs, and to manage expectations when negotiating irrigation transfer contracts. In planning new irrigation infrastructure, it is paramount to investigate not only which technologies are physically feasible and which are preferred by future users, but also the cost-benefit analyses and the environmental impact of each system. Physical suitability, cost-benefit analyses, and environmental impact assessments are outside of the scope of this study. This study instead focuses on farmer preferences, aiming to answer the following five research questions:

1. Which irrigation scheme technologies do farmers prefer?
2. To what extent are farmers willing to invest capital and unpaid labor in the *construction/set-up* of each type of irrigation scheme?
3. To what extent are farmers willing to invest capital and unpaid labor in the *maintenance* of each type of irrigation scheme?
4. To what extent are farmers willing to invest capital and unpaid labor in the *management* of each type of irrigation scheme?
5. Which socioeconomic factors affect farmers' willingness to invest in irrigation schemes?

The inclusion of unpaid labor as a form of investment makes this study unique. No other studies could be found on non-financial investment options for IMT. Given the financial constraints of smallholder farmers, non-capital investments may improve the success rates of IMT.

2. Materials and Methods

Three hundred smallholder farming households in Dedza District were sampled using stratification of randomization [2]. A list of Dedza District's 2,840 villages was acquired from the Ministry of Agriculture, Irrigation and Water Development. The statistical population was 242,519 households. The eight Traditional Authority Areas (TAs) of the district were used as the strata; 30 villages were randomly sampled from the strata proportionate to TA population. Up-to-date lists of the sampled households were then obtained from the district agricultural extension office. From these lists, ten households were randomly selected per village. The households were interviewed in May and June of 2014.

Farmers were asked to contemplate the hypothetical construction by the government of a new irrigation scheme in their village. It was explained that the scheme would be for communal use and that they could invest in the scheme by: working without pay on its construction; covering a share of the construction costs; working without pay to maintain it once built; covering a share of the maintenance costs; working without pay to manage it; and covering a share of the management costs. They were asked to rank their preferences for which irrigation technology the hypothetical new scheme would be, then they were asked how much labor and capital they would be willing to invest in the construction, maintenance, and management of each technology. These investment types (labor and capital), technologies (treadle pump [1], motorized pump, canal, and bound basin), and stages (construction, maintenance, and management) combine to make 24 investment categories. The enumeration team was trained to emphasize the fact that the irrigation scheme was purely hypothetical and that the farmers' identities would remain confidential.

Given financial and temporal constraints, this contingent valuation methodology was used without the addition of "cheap talk" scripts, follow-up certainty questions, or other tools to control for hypothetical bias. Findings in the literature are inconclusive on which, if any, methods can reliably mitigate hypothetical bias [1,3,7,10]. Furthermore, no studies could be found on the assessment of the willingness to invest in non-financial ways, as was done in this study. Choice experiments, which are less prone to hypothetical bias, are time consuming and the survey's resources were not sufficient for the use of choice experiments for different irrigation systems.

Individuals are known to report an inflated willingness to pay, especially when the good is a public one, such as an irrigation scheme [10]. Despite the emphasis given on the confidentiality of the survey's results and the hypothetical nature of the questions, it is possible that respondents over-stated their willingness to invest, hoping that their village would be chosen for a government program. The government should be acutely aware of this bias when planning a real-world IMT program, as the success of IMT depends on accurate budget estimates and tempered expectations.

Given the size and the geographical range of the survey sample, the respondents can be considered representative of the rural population of Dedza District. The average household size of the sample is five, and the average age of all household members is 23 years.[2] Household heads have an average age of 47 years, most are male (72%) and have a primary occupation as crop production (83%). The majority (52%) of household heads have not completed any level of formal education. All respondents are smallholder farmers; on average they operate 1.15 hectares of land.

Of the 300 households surveyed, 118 use some type of irrigation. Farmers reported that irrigation technology is either "important" or "very important" for obtaining output on 56% of all plots. However, irrigation is only used on about one-fifth of all plots, with bucket irrigation as the most-used technology (on 11% of all plots), followed by gravity-fed canal irrigation (5%), bound basin (2%), treadle pumps (1%), and motorized pumps (0.3%). Bucket irrigation, the most common type, is inexpensive but labor intensive and ineffective. Canal irrigation, the second most common type, entails costly infrastructure; those of the surveyed villages with canal irrigation are beneficiaries of government or donor projects that established the canal systems.

To investigate socio-economic determinants of respondents' willingness to invest in hypothetical irrigation

[1]A treadle pump uses human-powered pistons to extract groundwater from depths of up to 7 meters. The pistons are attached to large levers that the operator steps on to activate the suction.

[2] Unless otherwise stated, all statistical findings are for the agricultural year 2012/2013 (defined as November 2012 to October 2013).

schemes, ordinary least squares regression analyses were conducted. Regressions were run for both types of investment (unpaid labor and capital) in each investment stage (construction, maintenance, and management) to each of the four types of irrigation schemes (treadle pump, motorized pump, canal, and bound basin). Two of the 24investment categories, willingness to invest unpaid labor in the construction of treadle and motorized pumps, were not included because after the initial purchase of these technologies relatively little setup is required.

Each of the 22 regression analyses contained 12 independent variables: percent of household members that are working age males, social network score, per capita household net income, per capita number of parcels operated, per capita hectares of land cultivated, average distance to market from parcels, elevation of the household, gender of the main agricultural decision maker, education level of the main agricultural decision maker, risk self-assessment score, average importance of irrigation to yield on parcels, and access to credit score.

Following each regression analysis, diagnostic tests were run. The distribution of residuals and the variance inflation factor of each model was checked. The average variance inflation factor of all models was 1.29, indicating multicollinearity is not an issue (Chatterjee, Hadi & Price, 2000). Model specification was checked with the Ramsey Regression Equation Specification Error Test. After the models failed the Breusch-Pagan test for heteroscedasticity, the regressions were re-run using estimates of robust standard errors [14,16].

3. Results and Discussion

3.1. Willingness to Invest

When asked which technology they would prefer for the hypothetical scheme, the farmers' ranking, from the most preferred to the least preferred, is: motorized pump (most preferred by 41% of respondents), treadle pump (40%), gravity-fed canal (16%), and bound basin (3%).If a farmer deemed a type of technology unsuitable for their village's topography it was omitted from their ranking. Next, farmers were asked how much they would be willing to invest, in terms of unpaid labor and capital, in the construction, maintenance, and management of each type of scheme. Those results are presented in Table 1 and Table 2.

Table 1. Willingness to Invest Unpaid Labor

	To Construction *(hours per week)*	To Maintenance *(hours per year)*	To Management *(hours per year)*
Motorized Pump	N/A	36	24
Treadle Pump	N/A	28	24
Canal	6	10	10
Bound basin	2	0	0

Source: Own survey, 2014.

In Table 1 and Table 2, the median rather than the mean is given because it is closer to what the government could expect a village to invest, assuming all households would invest an equal share. The mean should not be used as it is positively skewed by a few farmers who are better-off, more eager, or possibly affected by hypothetical bias.

As the most preferred technology, the motorized pump also scores highly in all willingness to invest categories. According to informal interviews, the motorized pump is a much sought-after status symbol among farmers and is advertised on the radio by local agricultural dealers. Farmers did, however, express concerns about the cost and difficulty of obtaining the fuel needed to operate a motorized pump, as well as the cost and difficulty of repairing the pump. Treadle pumps, which did similarly well in the investment categories, have also been brought to farmers' attention on the radio as they have recently been promoted in the area by charitable groups. However, those farmers who are familiar with their use tend not to favor treadle pumps due to the physical exertion needed to operate them.

Table 2. Willingness to Invest Capital

	To Construction *(USD[3])*	To Maintenance *(USD per year)*	To Management *(USD per year)*
Motorized Pump	8.58	5.42	4.51
TreadlePump	9.03	6.32	4.51
Canal	2.71	1.81	1.35
Bound basin	0	0	0

Source: Own survey, 2014.

The threat of hypothetical bias to the accuracy of these willingness to invest estimates seems minor given how reasonable the estimates are. Less than 10% of respondents reported being willing to invest unpaid labor in a capacity that could be considered full-time employment. The capital investment responses also seem realistic as the medians are not more than four days' worth of wage labor.[4]

3.2. Socio-Economic Determinants of the Willingness to Invest

Regressions were run on the 22 models using estimates of robust standard errors. Thirteen of the models are as a whole statistically significant at the 10% level or better and 11 of the models pass regression diagnostics tests for multicollinearity and model specification. Both of the models that are statistically significant at the 10% level or better but do not pass the regression diagnostic tests, fail the Ramsey Regression Equation Specification Error Test, indicating that variables are missing from the model. All of the models, despite the use of robust standard error estimates, have right-hand conical distribution of residuals; those farmers who are willing to invest the most are motivated to do so by unknown factors.

The present explanatory variables in the models were selected for their importance to the theoretical framework, following extensive experimentation with different variable combinations. The missing explanatory variables are assumed to be unquantifiable or intangible, including possibly entrepreneurial spirit or generosity of respondents. A person's level of risk tolerance was hypothesized to be an intangible variable that would strongly affect willingness to invest, so an effort was made to quantify it with a risk self-assessment scale (Dohmen et al., 2012;

[3] US dollar values in this paper are converted from Malawian kwacha, and adjusted for purchasing power parity and inflation. Malawian kwacha, the local currency, was used during the survey. The average official exchange rate over the two-month period during which the survey took place (May and June, 2014) was 1 USD was equal to 387 MWK [13]. The average purchasing power parity adjusted for inflation was 1 USD was equal to 110.78 MWK during that same time [12,13,15].

[4] At the time of the survey, a person in Dedza could expect to earn 3.61 USD for a full day of hard labor (such as clearing a field or digging a canal).

Nielsen et al., 2013). The risk self-assessment scale either does not apply in this willingness to invest context, or risk tolerance itself is irrelevant, because the risk variable was only significant in one of the valid models.

The dependent variables of the 11 valid models and their significant explanatory variables are shown in Table A1 of the supporting file. Full results from all of the regression analyses are available from the corresponding author upon request. The regression results have low r-squared and adjusted r-squared values for the majority of the models, meaning that the independent variables in the models have little predictive power. It is important, therefore, to note that these models should be used for explanatory purposes only; there are small but reliable relationships between the independent and dependent variables.

Of the 12 explanatory variables included in each model, 11 are statistically significant in at least one of the models: percent of household members that are males of working age (statistically significant in five models), education level of the main agricultural decision maker (5), per capita number of hectares operated (5), social network score (4), perceived importance of irrigation to yield (4), elevation (4), gender of main agricultural decision maker (4), average distance to market from parcels (3), credit access score (2), per capita number of parcels operated (1), and risk self-assessment score (1).

As hypothesized, households with a higher percentage of working-age males are willing to invest more in several categories. It was expected that the impact of labor endowment would be strongest in the investment of unpaid labor categories, but it was not clearly delineated in that way. This suggests that the value of extra labor affects willingness to invest indirectly through other factors like social network strength.

The education level of the household's main agricultural decision maker is a powerful explanatory variable in the willingness to invest in canals models, but not in the treadle or motorized pump models. This may be because canal irrigation is more complex; it is more difficult to set-up, maintain, and manage. Those who are better educated may be better prepared to take on the challenge of canal irrigation. More educated respondents may also be better informed of the drawbacks of treadle pump and motorized pump operation.

Counter-intuitively, the per capita number of hectares of land cultivated is negatively correlated with willingness to invest in five of the models. It was originally assumed that households with thinly spread labor would be most interested in gaining access to efficient irrigation, thus relieving the stress on their labor endowment, and so would invest generously. Upon further inspection, the negative finding is logical given that four of the negative correlations are in willingness to invest unpaid labor categories. Those households with more land to operate per person will be less likely to spare labor to volunteer on an irrigation project; they would have to take the short-term view of the future, as the poor often must to survive, and satisfy their immediate needs.

As expected, a household's social network strength and its perception of the importance of irrigation to yields are powerful explanatory variables in the models. Both are statistically significant in four models. Because the use of public goods, such as an irrigation scheme, requires cooperation and inclusive planning, households with stronger social networks can be expected to be willing to invest more. Active participation in social networks both requires and fosters the same social skills needed to successfully operate a community-owned irrigation scheme.

The elevation variable, however, has unexpected results. It was hypothesized that the higher a respondent's elevation, the less they would be interested in irrigation, given their cooler microclimate and heavier precipitation. The regression results give positive coefficients for elevation in four of the models; many households that are located at high elevations are in fact willing to invest in irrigation projects. Villages at high elevations are generally more remote, so their occupants may be more eager to take on income-generating endeavors.

It was hypothesized that female main agricultural decision makers would invest more in irrigation schemes given their stronger social ties and need to innovate to support their household. It is generally women who irrigate the fields with watering buckets, so they were expected to be particularly eager to adopt more efficient irrigation technology. The results show this to be an over simplification. Being female positively impacts willingness to invest unpaid labor in the maintenance of both motorized pumps and canal irrigation, whereas being male positively impacts willingness to invest capital in the management of motorized pumps, and unpaid labor in the construction of canals. Gender is not found to be a statistically significant explanatory variable in any other models.

Of the 12 independent variables, the one that is not found to be statistically significant in any of the models is per capita net household income. Although great pains were taken to collect accurate income levels, the data proved unreliable. The recall period of over one year was too long, and given the education level of respondents, innumeracy is suspected.

If farmers did not think a certain technology was feasible in their village because of topography, their willingness to invest in any way to that technology was omitted. Bound basin, for example, was deemed unfeasible by 111 farmers, so there are only 189 observations for the respective models. Similarly, there are only 210 observations for canal models. Because of the low number of observations, none of the bound basin models are statistically significant.

4. Conclusion

This study aimed to shed light on whether smallholder farmers would be willing to invest unpaid labor in irrigation schemes. To the best of our knowledge, this is the first study to do so, opening up another dimension of IMT research. The results show that farmers are indeed willing to invest unpaid labor, instead of or in addition to capital. IMT planners may use this information to develop individually tailored investment packages for IMT stakeholders.

Despite the lack of predictive power of the models, the explanatory value of the models is useful for policy recommendations. A larger household labor endowment, a higher education, a lesser amount of land operated, a stronger social network, a higher perceived importance of irrigation, and a higher elevation are all found to be characteristics of households that are willing to invest more. These findings are important to future targeting and implementation of IMT programs. New IMT programs should target areas where interest is strong, such as villages at higher elevations where respondents were enthusiastic investors in several categories. The perception that irrigation is important to crop yields, as well as the strength of one's social network are strong explanatory variables in several categories; both of these variables can also be expected to motivate farmers to stay involved in an IMT program and to honor their investment obligation. In view of the need for realistic investment agreements, households could be offered a combination of ways in which to invest, which would increase the likelihood that commitments would be filled. For example, a household with a thinly spread labor endowment, due to a small percentage of working age males or a high per capita amount of land cultivated, could be offered an investment package that requires more capital and less unpaid labor.

Successful IMT requires clear communication of expectations among stakeholders. This study sought to create predictive models that would help ease the burden of communication by establishing safe assumptions that project leaders could use in their planning of irrigation systems. This study confirmed that the best path to having water resources effectively managed at the local level is through an open and inclusive dialogue. The existence of intangible independent variables caused the models to have little predictive value, but they are useful as explanatory models.

The models could be improved with a larger sample size. More observations might reduce the relative importance of the intangible variables and bring to the foreground the predictive power of the quantifiable variables. Ideally, the expanded sample would include enough respondents in lowland areas, where bound basin schemes are feasible, for the models of willingness to invest in bound basin schemes to become statistically significant. In the interviews, respondents skipped willingness to invest questions for irrigation types they deemed infeasible in their village. This would not be an issue in a real irrigation project as the area would first be surveyed, then the appropriate irrigation technology would be proposed.

This study was limited to the use of stated willingness to invest; because the irrigation schemes were hypothetical, actual investments could not be measured. It is one thing for a respondent to say how much they will invest in a scheme, and another for them to actually make the investment, so hypothetical bias may be an issue. However, the data shows reasonable and conservative willingness to invest levels, so hypothetical bias does not seem to be a factor. Irrespective of academic research findings, IMT managers must err on the conservative side when accounting for hypothetical bias in their planning of specific projects.

Poor smallholder farmers often must take the short-term view of the future, deferring long-term goals to meet immediate needs. Meeting basic human needs for survival will always override honoring commitments to non-essential activities like IMT; program managers need to be understanding of this fact and make accommodations in their financial and temporal planning. Even the smallest investment in an irrigation scheme could be a hardship for a household, so future IMT programs may consider offering financial support, especially during the construction phase of IMT when the burden of investment will be the heaviest. Further, farmers' cash flows and harvest seasons need to be accounted for in IMT planning. The investment levels reported in this study are from data collected immediately after harvest, when farmers had finished the bulk of their hard labor for the season, had full grain stores, and had cash on hand from crop sales. To manage stakeholder expectations, the seasonality of available labor and capital must be accommodated.

The success of IMT depends on the establishment of accurate and attainable goals by all stakeholders. If all participants know what to expect from each other and what will be expected of them, then IMT will foster the effective management of water resources, the empowerment of local people, and the alleviation of financial strain on national government.

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Statement of Competing Interests

The authors have no competing interests.

List of Abbreviations

IMT – Irrigation Management Transfer
TA – Traditional Authority Area

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Supporting File

Table A1. Statistically Valid Regressions and their Explanatory Variables

Dependent Variable (Willingness to Invest)	*Explanatory Variable*	*Beta Coefficient*
Unpaid labor in maintenance of treadle pump		
	Elevation***	.1125664
	Percent male labor**	.1730477
	Per capita hectares of land**	-.1483344
Capital in maintenance of treadle pump		
	Social network score**	.1391224
	Percent male labor*	.1102946
	Importance of irrigation*	.112307
Capital in construction of motor pump		
	Per capita hectares of land**	-.1027555
	Per capita number of parcels**	.1444672
	Risk self-assessment score*	.0925521
Unpaid laborin maintenance of motor pump		
	Elevation***	.1437741
	Credit access score*	.1509102
	Average distance to market*	-.0748795
	Gender of decision maker*	.0950254
Unpaid labor in management of motor pump		
	Elevation***	.1242597
Capital in management of motor pump		
	Average distance to market**	.1384289
	Gender of decision maker*	-.1043344
Unpaid labor in construction of canal		
	Per capita hectares of land**	-.1515848
	Gender of decision maker**	-.1624614
	Education level of decision maker**	.142801
	Importance of irrigation*	.1303175
Unpaid labor in maintenance of canal		
	Education level of decision maker***	.3388762
	Percent male labor*	.1517368
	Per capita hectares of land*	-.0907487
	Gender of decision maker*	.1224326
Capital in maintenance of canal		
	Education level of decision maker**	.2070039
	Percent male labor**	.1855371
	Social network score**	.1654136
	Importance of irrigation**	.1200562
Unpaid labor in management of canal		
	Social network score**	.17646
	Per capita hectares of land**	-.1143898
	Average distance to market**	-.1165058
	Education level of decision maker**	.1868732
	Elevation*	.114369
Capital in management of canal		
	Social network score***	.2878016
	Education level of decision maker***	.1694977
	Credit access score*	-.1290066
	Percent male labor*	.1253275
	Importance of irrigation*	.1104252

Source: Own survey, 2014

*, **, *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.