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MICROECONOMIC ANALYSIS OF POLICIES ADDRESSING FOOD SECURITY, WATER AND ENERGY TRADE-OFFS IN MALAWI

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EXECUTIVE SUMMARY

The increasing pressure from the world's population on limited natural resources has reached an urgent level. The global demand for water, food, and energy is unsustainable, and poses a threat to human health, political stability, and environmental well-being. The poor in developing countries are most vulnerable to the negative effects of the exploitation of constrained resources, and the segregation of development programs by sector means that policy interventions do little to help. Currently, development policies are created in isolation from one another, within their own sectoral realms, and inter-sector coordination is rare. Policy interventions that affect more than one sector are key to holistic, sustainable development, but because they face an ownership issue, not falling under any one sector's jurisdiction, they often go unaddressed. The alternative to the status quo is the use of a nexus perspective, which emphasizes the interconnectedness of sectors and seeks to implement policy interventions with the best net outcomes. Policy makers are encouraged to adopt "systems thinking", to resist over-focused investments and interventions, and to seek regulatory cooperation.

The body of nexus literature is growing mainly with the establishment of theoretical frameworks and macroeconomic studies that model outcomes of nexus interventions. This thesis contributes to the pool of nexus literature with microeconomic studies that are evaluated from the perspective of the food-energy-water (FEW) nexus. Microeconomic analysis is valuable to the nexus perspective not only because it informs macroeconomic models, but also because it provides empirical evidence of nexus forces at work.

The subjects of the three studies contained in this thesis are smallholder farmers in Dedza, Malawi. The first study investigates the farmers' willingness to invest in communally-owned irrigation schemes and the household socioeconomic characteristics that determine that willingness. The study is intended to inform Irrigation Management Transfer (IMT) programs, to help smooth the process of the transfer of irrigation scheme ownership from the government to local stakeholders. The promotion of IMT programs is considered a FEW nexus intervention because irrigation affects not only the water sector, but also the energy and food sectors. While widespread irrigation adoption may negatively impact the water sector and reduce the potential for hydropower in the energy sector, it can also be expected to improve yields and thus security in

the food sector. The study found that farmers are willing to invest unpaid labor in addition to, or instead of capital, suggesting that investment packages should be tailored to stakeholders' endowments. Inclusive dialogue and clear investment expectations for stakeholders are key to the long-term success of IMT projects.

The second study in this thesis elicits smallholder farmers' preferences for a conditional cash transfer (CCT) over a fertilizer subsidy coupon, with the intent of presenting policy makers with an alternative to Malawi's Farm Input Subsidy Program (FISP). The narrow focus of the FISP, combined with its astronomical budget and disputed impact, indicate that it is time for an alternative, nexus-oriented intervention. The conditionality of a CCT means it can be targeted directly at certain sectors, and because beneficiaries are free to spend the cash as they choose, the impact will be spread over all three sectors. The study found that as a group, the farmers are reluctant to accept the CCT over a fertilizer subsidy. However, the most vulnerable respondents, those households with the lowest incomes, with female main decision makers, and located in remote villages, are more likely to prefer the CCT. A well-targeted, transparent CCT program has the potential to reach the most at-risk households and bring positive developments to the FEW nexus in a way the FISP cannot.

The third study in this thesis explores smallholder farmers' willingness to pay (WTP) for improved cookstoves (ICS) and the socioeconomic characteristics that determine their WTP, to assist ICS promoting programs with pricing and targeting. Widespread sustained ICS adoption and the resulting fuel savings would directly affect the food and energy sectors, and indirectly affect the water sector. The high morbidity rates caused by reliance on biomass fuels for cooking would decline with sustained ICS adoption and proper use, resulting in human health improvements that would affect all three nodes of the nexus. There would be further indirect effects on all three sectors resulting from advancements in gender equality and climate change mitigation. The study found household dietary diversity and annual net income per capita to be positively correlated with WTP, while fuel expenditures and the presence of cooking-related ailments are negatively correlated with WTP, highlighting the need for strategic stove promotion programs.

While the findings of these studies have interesting implications for the FEW nexus, the interventions in question should be applied in an economy-wide model to determine the nexus

effects. Such coordination of micro- and macroeconomic research, coupled with the inter-sector perspective, characterize the nexus approach and the future of development policy.

ZUSAMMENFASSUNG

Der zunehmende Bevölkerungsdruck auf begrenzte natürliche Ressourcen hat ein kritisches Niveau erreicht. Der globale Bedarf an Wasser, Nahrungsmitteln und Energie ist nicht nachhaltig und stellt eine Bedrohung für die menschliche Gesundheit, die politische Stabilität und die Umwelt dar. Arme in Entwicklungsländern sind am stärksten von negativen Auswirkungen der Ausbeutung von begrenzten Ressourcen betroffen. Die Trennung von Entwicklungsprogrammen nach Sektoren führt dazu, dass politische Interventionen wenig zur Lösung dieses Problems beitragen. Derzeit werden entwicklungspolitische Maßnahmen isoliert voneinander, innerhalb ihrer eigenen Sektoren geschaffen, und es gibt wenig Koordination zwischen den Sektoren. Sektorübergreifende politische Maßnahmen sind unablässig für eine ganzheitliche, nachhaltige Entwicklung, doch weil sie nicht unter die Zuständigkeit eines einzelnen Sektors fallen und Verantwortlichkeiten nicht klar sind, werden sie oft nicht durchgeführt. Die Alternative zum Status Quo ist die Verwendung einer Nexus-Perspektive, die die Vernetzung von Sektoren unterstreicht und politische Interventionen mit den besten Nettowirkungen umsetzt. Politische Entscheidungsträger werden dazu aufgefordert "systemisch“ zu denken, thematisch zu sehr fokussierten Investitionen und Interventionen zu widerstehen und regulatorische Zusammenarbeit zu suchen.

Die Literatur zum Nexus wächst vor allem mit der Etablierung von theoretischen Bezugsrahmen sowie makroökonomische Studien, die Ergebnisse von Nexus-Interventionen modellieren. Die vorliegende Arbeit leistet einen Beitrag zur Nexus-Literatur mit mikroökonomischen Studien, die aus der Perspektive des Nexus Nahrung-Energie-Wasser (FEW) ausgewertet werden. Eine mikroökonomische Analyse ist für die Nexusperspektive nicht nur deshalb wertvoll, weil sie Daten für makroökonomische Modelle, sondern auch, weil sie empirische Beweise für Nexus-Kräfte liefert.

Gegenstand der drei Studien in der vorliegenden Arbeit sind Kleinbauern in Dedza, Malawi. Die erste Studie untersucht die Bereitschaft der Landwirte, in gemeinschaftlich genutzte Bewässerungsprogramme zu investieren sowie die sozioökonomischen Charakteristiken der Haushalte, die diese Bereitschaft bestimmen. Die Studie soll den Prozess der Übertragung von Projektverantwortung für das Bewässerungsmanagement-Transferprogramm (IMT) von der Regierung zu lokalen Stakeholdern erleichtern. Die Förderung von IMT-Programmen gilt als FEW-

Nexus-Intervention, da Bewässerung nicht nur den Wasser-, sondern auch den Energie- und Nahrungsmittelsektor betrifft. Während Bewässerung in der Landwirtschaft den Wassersektor negativ beeinflussen und das Wasserkraftpotenzial im Energiesektor verringern kann, kann mit einer weiteren Übernahme von Bewässerung gerechnet werden, die Erträge und somit Ernährungssicherheit verbessert. Die Studie stellt fest, dass Landwirte bereit sind, unbezahlte Arbeit statt oder zusätzlich zu Kapital zu investieren, was darauf hindeutet, dass die Investitionen auf die Stakeholder zugeschnitten sind. Inklusiver Dialog und klare Investitionserwartungen für Stakeholder sind Schlüsselelemente für den langfristigen Erfolg von IMT-Projekten.

Die zweite Studie in dieser Arbeit untersucht die Präferenzen von Kleinbauern für ein Geldtransferprogramm (CCT) sowie Düngergutscheinen. Ziel dieser Studie ist es, politischen Entscheidungsträgern in Malawi eine Alternative zum Düngersubventionsprogramm (FISP) zu präsentieren. Der enge Fokus des FISP, das beträchtliche Budget und umstrittene Auswirkungen deuten auf die Notwendigkeit einer alternativen, nexusorientierten Intervention hin. Die Konditionalität eines CCT bedeutet, dass es direkt auf bestimmte Sektoren ausgerichtet werden kann und weil die Begünstigten frei entscheiden, wofür sie das Geld ausgeben, werden die Auswirkungen auf alle Sektoren verteilt. Die Studie stellt fest, dass die Mehrheit der Landwirte den Düngerzuschuss vor dem CCT den Vorzug gibt. Allerdings wird das CCT von Haushalten in abgelegenen Dörfern, denjenigen mit den niedrigsten Einkommen und denjenigen bei denen eine Frau wichtigster Entscheidungsträger ist, bevorzugt. Ein zielgerichtetes, transparentes CCT-Programm hat im Gegensatz zum FISP das Potenzial, diese am meisten gefährdeten Haushalte zu erreichen und positive Entwicklungen zum FEW-Nexus beizutragen.

Die dritte Studie untersucht die Zahlungsbereitschaft(WTP) von Kleinbauern für verbesserte Kochherde (ICS) und die sozioökonomischen Merkmale, die die WTP bestimmen, mit dem Ziel, die Förderung von ICS-Programmen mit Preisgestaltung und Targeting zu unterstützen. Eine nachhaltige Verbreitung von verbesserten Kochherden und die daraus resultierenden Treibstoffeinsparungen würden Nahrungsmittel- und Energiesektor direkt und den Wassersektor indirekt beeinflussen. Die hohen Morbiditätsraten, die durch die Abhängigkeit von Biomasse zum Kochen verursacht werden, würden mit anhaltender ICS-Übernahme und korrektem Gebrauch sinken, was zu Verbesserungen der menschlichen Gesundheit führt, die alle drei Nexusknoten betreffen. Es gibt weitere indirekte Auswirkungen auf alle drei Sektoren, die sich aus Fortschritten

bei der Gleichstellung der Geschlechter und dem Klimaschutz ergeben. Die Studie ergab, dass die Ernährungsvielfalt der Haushalte und das jährliche Nettoprokopfeinkommen positiv mit der Zahlungsbereitschaft korrelieren, während Treibstoffverbrauch sowie kochbedingte Erkrankungen negativ mit der Zahlungsbereitschaft korrelieren, was die Notwendigkeit von strategischen Herdförderungsprogrammen hervorhebt.

Während die Ergebnisse dieser Untersuchungen interessante Implikationen für den FEW-Nexus haben, sollten die betreffenden Interventionen in einem gesamtwirtschaftlichen Modell angewendet werden, um die Nexus-Effekte zu bestimmen. Diese Koordination mikro- und makroökonomischer Forschung gepaart mit einer sektorübergreifenden Perspektive kennzeichnet den Nexusansatz sowie die Zukunft von Entwicklungspolitik.

List of Abbreviations

ADMARC – Agricultural Development and Marketing Corporation

BMZ – German Ministry of Development and Economic Cooperation

CCT – conditional cash transfer

ETIP – Extended Targeted Input Program

FAO – Food and Agriculture Organization

FEW nexus – food-energy-water nexus

FISP – Farm Input Subsidy Program

ICS – improved cookstove

IFPRI – International Food Policy Research Institute

IMT – irrigation management transfer

MWK – Malawian kwacha (Malawi's national currency)

NGO – non-governmental organization

NPK – nitrogen-phosphorus-potassium fertilizer

OLS – ordinary least squares

Ramsey RESET – Ramsey Regression Equation Specification Error Test

TA – Traditional Authority Area

USD – United States dollar

WTP – willingness to pay

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1. General Introduction

This section introduces the country of study, the Republic of Malawi, and provides a conceptual framework for the thesis. The topics and objectives of the three studies contained within this thesis are described. At the end of this introduction is an outline of the thesis.

1.1 Introduction to Malawi

A former British colony and relatively newly established democratic nation, Malawi faces many of same challenges as other Sub-Saharan countries, including rapid population growth, scarcity of arable land, corruption, and an HIV/AIDS epidemic (Central Intelligence Agency, 2016). The country's economy is further constrained by poor infrastructure, limited market access, and a labor force weakened by health issues and lack of education, putting the GDP growth rate at 3% (2015 estimate) (Central Intelligence Agency, 2016; International Fund for Agricultural Development, 2016) and placing Malawi at position number 160 of 182 on the Human Development Index (International Fund for Agricultural Development, 2016; United Nations Development Programme, 2009).

Among Malawi's population of 16.8 million, 74% live below the 1.25 USD per day income poverty line and 90% live below the 2 USD (International Fund for Agricultural Development, 2016; The World Bank, 2016; United Nations Development Programme, 2009). About 85% of Malawians live in rural areas, of whom 90% are smallholder farmers; they are often trapped in poverty by recurring environmental shocks, like droughts and floods, that harm crop yields and cause food price hikes (International Fund for Agricultural Development, 2016; The World Bank, 2016). Agricultural production is low, and smallholders are generally stuck in subsistence farming (International Fund for Agricultural Development, 2016; The World Bank, 2016). Malawians' low yield problems are compounded by both increasing population pressure on land resources and inadequate post-harvest technology (International Fund for Agricultural Development, 2016; The World Bank, 2016). Since 1968 average land holdings have decreased from 1.5 ha to 0.8 ha and post-harvest losses comprise about 40% of production (International Fund for Agricultural Development, 2016; The World Bank, 2016).

Numerous factors contribute to Malawi's stifling poverty levels. This thesis concentrates on three: the limited use of efficient irrigation technologies by smallholder farmers, the exhaustion of the agricultural budget by a poorly executed maize subsidy, and the rapid destruction of forest resources as a result of inefficient fuel use. Policy interventions that may improve these issues are the expansion of irrigation management transfer programs, the replacement of Malawi's current fertilizer subsidy program with a conditional cash transfer program, and the promotion of sustained adoption of improved cookstoves, respectively. These three policy interventions are interrelated when viewed from a nexus perspective.

1.2 Conceptual Framework

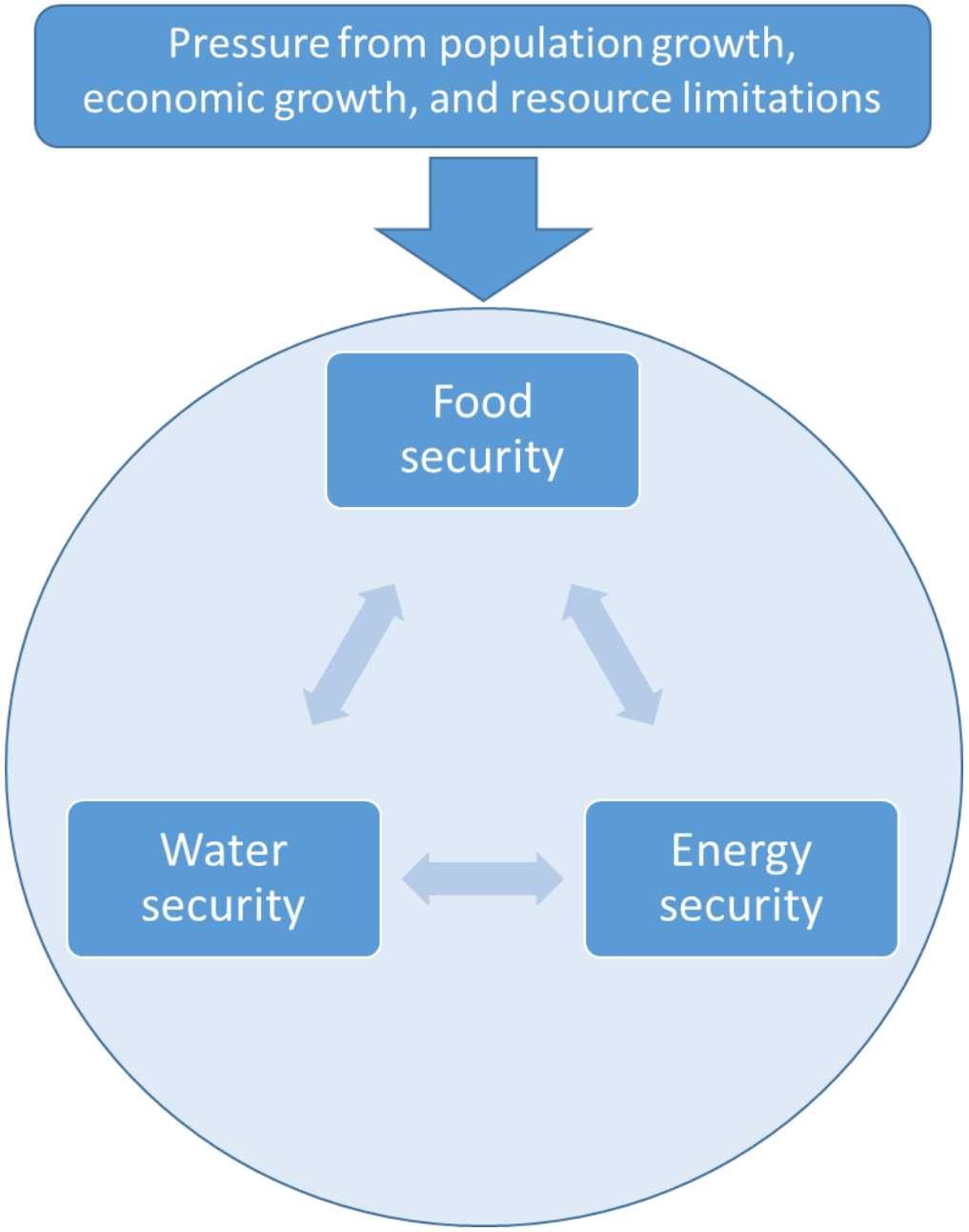
1.2.1 Nexus Perspective

In the development policy context, a nexus represents the interconnectedness of sectors. A nexus is best conceptualized with the aid of examples. In seeking improvements in one sector there may be trade-offs in another. For example, by increasing biofuel production for the benefit of the energy sector the water sector may suffer because of the expansion of irrigation needed for biofuel crop cultivation (Hussey & Pittock, 2012). Nexus policy relationships are not always characterized by trade-offs; they can be mutually beneficial. For example, an initiative to reduce the amount of water wasted by households would benefit both the water sector and the energy sector as the conveyance of less water through plumbing networks would require less energy (Hussey & Pittock, 2012). The use of a nexus perspective in policy making is based in new institutional economics (Kherallah & Kirsten, 2002) and is a relatively new concept having first emerged on the development policy stage in 2011 at the Bonn Nexus Conference and the World Economic Forum in Davos (Bizikova, Roy, Swanson, Venema, & McCandless, 2013; Gulati, Jacobs, Jooste, Naidoo, & Fakir, 2013; World Economic Forum, 2011).

The indispensability of the food, water, and energy sectors have made them the sectors of focus in much of the nexus literature (Bazilian et al., 2011; Bizikova et al., 2013; Gulati et al., 2013; Hellegers, Zilberman, Steduto, & McCornick, 2008; Hoff, 2011; Nielsen et al., 2015; Rasul, 2014; Villarroel Walker, Beck, Hall, Dawson, & Heidrich, 2014). Many trade-offs and synergies, in addition to those mentioned above, are described in the literature, which varyingly refers to the food-energy-water security nexus as the FEW nexus, the EWF nexus, or the WEF nexus. Figure 1.1

depicts the interconnectedness of the three sectors in the FEW nexus. The energy sector faces trade-offs from water sector developments including the operation of desalination plants, the inter-basin transfer of water, and the pumping of groundwater (Bazilian et al., 2011; Hussey & Pittock, 2012; Pittock, 2011; Shah, Scott, Kishore, & Sharma, 2003). The water sector faces trade-offs from energy sector developments including the operation of hydropower plants and the cultivation of biofuels (Bazilian et al., 2011; Hellegers et al., 2008; Hussey & Pittock, 2012). The complexity of the mutual reliance of the energy sector and the water sector present a major challenge to policy makers (Hussey & Pittock, 2012). The water sector also faces trade-offs from food sector developments, particularly the increased use of irrigation (Bazilian et al., 2011). Sectoral trade-offs and synergies in the nexus can be at the regional or global level. At the regional level, for example, activities of upstream communities affect the ability of downstream communities to make use of water for irrigation, hydropower, and drinking (Rasul, 2014). At the global level, for example, the use of biomass fuels for cooking increases atmospheric warming (Rasul, 2014).

Figure 1.1: Food-Energy-Water Security Nexus



Source: Adapted from Bazilian et al., 2011; Nielsen et al., 2015

Currently, potential policy interventions that affect more than one sector face an ownership issue as they do not belong to one ministry or department, responsibility is disputed, and so they often go unaddressed (Ruiz-Mercado, Masera, Zamora, & Smith, 2011). Assuming a nexus perspective could turn the ownership problem into an advantage, as resources could be pooled from all involved sectors. Researchers encourage policy makers to adopt "systems thinking", to

resist over-focused investments and interventions, and to seek regulatory cooperation (Bazilian et al., 2011; Bizikova et al., 2013; Hussey & Pittock, 2012; Scott et al., 2011). The urgency with which the nexus perspective is promoted is due to the world's increasing population pressure on limited natural resources (Bizikova et al., 2013; World Economic Forum, 2011). By 2030, the global demand for water, food, and energy is expected to increase by up to 50%, possibly causing political instability and environmental harm (Bizikova et al., 2013; World Economic Forum, 2011). The poor in developing countries are the most susceptible to the negative effects of these pressures (Bazilian et al., 2011; Bizikova et al., 2013; Hoff, 2011; World Economic Forum, 2011).

Because of government structuring and budget allocating, the links between sectors are largely ignored and policies are developed separately (Hussey & Pittock, 2012). In cases where sectors are considered simultaneously, concern for the environment is usually the unifying factor (Bazilian et al., 2011). Using the nexus perspective, the economy and sectoral security, which are stronger political impetuses than the environment, become the unifying factors (Bazilian et al., 2011). The scopes of the resource sectors make the use of the nexus perspective in policy making a major challenge, and the complexity of their interrelatedness means that researchers have been slow to develop support tools (Bazilian et al., 2011).

Several studies have now established quantitative frameworks for nexus perspectives (Mu & Khan, 2009; Schuenemann, Thurlow, & Zeller, 2017; Villarroel Walker et al., 2014; Zhu, Ringler, & Cai, 2007). The models, which discern sector linkages *a priori*, serve to assist policy makers in understanding the effects of interventions across sectors, providing much needed risk assessment (Bazilian et al., 2011; Hussey & Pittock, 2012). Apart from macroeconomic modelling, which can assess nexus relationships quantitatively at the country and sectoral level, the quantitative studies contained in this thesis are done at the microeconomic scale and not only help to provide empirical results for the calibration and validation of macroeconomic and sectoral models but also provide micro-level insights into the behavior of producers and consumers of food, energy and water.

1.2.2 Nexus Policy Interventions

This thesis and the three studies within it form a part of the International Food Policy Research Institute's (IFPRI) project, "Policies and Institutions for Achieving the Virtuous Food-Energy-Water Nexus in Sub-Saharan Africa", which is funded under a research grant by the German Ministry of Development and Economic Cooperation (BMZ). The goal of IFPRI's food-energy-water

security nexus (FEW nexus) project is to encourage policy makers to use the nexus perspective when creating interventions (Nielsen et al., 2015). IFPRI's FEW nexus project uses Malawi and Mozambique as its case study countries, and includes both macroeconomic and microeconomic modelling. The IFPRI Discussion Paper titled, "The-Food-Energy-Water Security Nexus: Definitions, Policies, and Methods in an Application to Malawi and Mozambique" (Nielsen et al., 2015) explains in great detail the project's components. It also provides its own unique definition of the FEW nexus:

> *The food-energy-water security nexus encompasses synergies and trade-offs between food, energy, and water security that are impacted by endogenous and exogenous drivers and cannot be captured if these sectors are analyzed in isolation.* (Nielsen et al., 2015)

This thesis contributes findings from microeconomic studies on nexus interventions in Malawi.

The first study in this thesis investigates smallholder farmers' willingness to invest in communally-owned irrigation schemes and the household socioeconomic characteristics that determine that willingness. The study is intended to inform Irrigation Management Transfer (IMT) programs, to smooth the process of the transfer of irrigation scheme ownership from state to local stakeholders. The promotion of IMT programs is considered a FEW nexus intervention because irrigation affects not only the water sector, but also the energy and food sectors. Irrigation may have negative impacts on water supplies, and the use of irrigation by upstream communities may affect the extent to which downstream communities can use water for irrigation, drinking, and hydropower (Rasul, 2014). There is, however, great potential for irrigation to make a positive impact on the food sector by increasing yields and extending growing seasons (Bazilian et al., 2011).

The second study in this thesis elicits smallholder farmers' preferences for a conditional cash transfer (CCT) over a fertilizer subsidy coupon, with the intent of presenting policy makers with an alternative to Malawi's Farm Input Subsidy Program (FISP). As a FEW nexus intervention, the FISP affects the food sector, as well as the water and energy sectors. The subsidy makes fertilizer affordable to more smallholder farmers, and allows them to increase their maize yields, impacting the food sector. Increased cropping requires increased irrigation, which affects the water sector. The FISP is focused primarily on maize yields, a narrow focus that crowds out other food crops and biofuel crops, in terms of both land allocation and the national agricultural budget, which affects the food and energy sectors (Nielsen et al., 2015). The alternative to the FISP that is

presented, a CCT, is also a FEW nexus intervention. The conditionality of CCTs can be used to directly target certain sectors. In the case of this hypothetical CCT, the cash would be provided on the condition of adoption of agroforestry techniques, providing benefits to the food sector through crop diversity, as well as indirect effects on the water and energy sectors. Because CCT recipients are free to spend the cash any way they choose, the CCT would impact all three sectors. Beneficiaries may choose to make investments in their agricultural production, which would affect all three sectors directly, or they may choose to invest in non-agricultural business, transportation, or education, which would indirectly affect all three sectors.

The third study in this thesis explores smallholder farmers' willingness to pay (WTP) for improved cookstoves (ICS) and the socioeconomic characteristics that determine their WTP, to assist ICS promoting programs with pricing and targeting. Widespread ICS adoption directly affects the food and energy sectors, and indirectly affects the water sector. The fuel efficiency of the stoves may allow users to consume a more diverse diet and decrease their fuel consumption (Nielsen et al., 2015). The lower demand for firewood and charcoal resulting from the fuel efficiency will slow deforestation and thus erosion, which in turn will improve water quality (García-Frapolli et al., 2010). Further, the public health benefits from a reduction in use of biomass as fuel will affect all three sectors indirectly, as will the resulting climate change mitigation effects (Bensch & Peters, 2012; El Tayeb Muneer & Mukhtar Mohamed, 2003; Fitzgerald et al., 2012; Hanna, Duflo, & Greenstone, 2012; Jan, 2012; Martin II, Glass, Balbus, & Collins, 2011).

1.3 Studies and Objectives

The three studies that constitute the body of this thesis are linked by their basis in the nexus intervention perspective. Below are the topics and objectives of each study.

Research Topic 1: Willingness to invest in irrigation schemes and socioeconomic determinants thereof

This study seeks to provide insight into smallholder farmers' preferences for four different irrigation technologies, and the extent to which they are willing to invest in communally-owned irrigation schemes, as well as the socioeconomic traits and conditions that drive that willingness. The following five questions are explored:

(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?

Research Topic 2: Preferences for a conditional cash transfer over a fertilizer coupon and socioeconomic determinants thereof

With the aim of exploring alternatives to Malawi's current fertilizer subsidy, this study determines smallholder farmers' preferences for a CCT over a fertilizer coupon. A choice experiment is used to elicit the preferences, survey questions investigate bias against the cash transfer as well as uses for the cash, and regression models provide insight into which socio-economic characteristics influence the preferences. Four research questions are addressed:

(1) Do farmers generally prefer the CCT or the fertilizer subsidy?
(2) Among farmers who never prefer the CCT, why do they always prefer the fertilizer subsidy?
(3) If farmers were to receive a CCT of 380 USD,[1] how would they spend the money? How do responses differ between the main agricultural decision maker and their spouse?
(4) Which socioeconomic factors affect preferences for the CCT or the fertilizer subsidy?

Research Topic 3: Willingness to pay for improved cookstoves and socioeconomic determinants thereof

[1] US dollar values in this thesis 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 (OANDA, 2015). The average purchasing power parity adjusted for inflation was 1 USD was equal to 110.78 MWK during that same time (NSO, 2015; OANDA, 2015; The World Bank, 2015).

This study explores which socioeconomic traits influence consumers' stated willingness to pay (WTP) for two types of ICS: a clay stove and a rocket stove. Findings are compared with those from studies done in other regions with different stoves (El Tayeb Muneer & Mukhtar Mohamed, 2003; Jan, 2012; Mobarak, Dwivedi, Bailis, Hildemann, & Miller, 2012; Pine et al., 2011; Takama, Tsephel, & Johnson, 2012). Given the study's objectives, four research questions emerge:

(1) What is the average WTP for the clay stove?

(2) What is the average WTP for the rocket stove?

(3) Which socioeconomic characteristics influence a households' WTP for the clay stove?

(4) Which socioeconomic characteristics influence a households' WTP for the rocket stove?

1.4 Outline of Thesis

This thesis is organized as follows: Chapter 2 covers Research Topic 1, exploring smallholder farmers' willingness to invest in terms of time and money to different irrigation schemes. Chapter 3 covers Research Topic 2, examining the stated preferences for a CCT over a fertilizer coupon as elicited by a choice experiment. Chapter 4 covers Research Topic 3, assessing respondents' WTP for two different ICS and the socioeconomic factors behind that willingness. Chapter 5 concludes the thesis by viewing the studies' results through the nexus lens and providing policy recommendations.

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2. SMALLHOLDER FARMERS' WILLINGNESS TO INVEST IN IRRIGATION SCHEMES IN DEDZA, MALAWI

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2.1 Introduction

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 (Garces-Restrepo et al., 2007). 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 investigate 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. 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. 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. Policy makers are encouraged to tailor IMT projects to individual households' abilities to invest capital, unpaid labor, or a combination of the two.

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 (Meinzen-Dick & Knox, 1999). 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 (Garces-Restrepo et al., 2007), 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 (1999), 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 monumental and 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 (Meinzen-Dick & Knox, 1999).

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 (Ferguson & Mulwafu, 2005; Mulwafu & Nkhoma, 2002). 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 (FAO, 2006; Kaluwa et al., 1997). 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 (Nkhoma & Mulwafu, 2004).

IMT has been on Malawi's policy agenda since the 1990s. The 1998 National Irrigation Policy and Development Strategy outlined procedures to repair rundown schemes, then transfer their ownership to farmer organizations (Malawi Government, 1998). Accordingly, the rehabilitation and handover of 16 schemes was attempted by the Technical Cooperation Project funded by the Food and Agricultural Organization (FAO) (Malawi Government, 1999). Due to the lack of funds for rehabilitation, lack of a detailed program for participating farmers, and the fact that the pilot process had not been well-documented, this project was a failure (Malawi Government, 2000).

A second attempt at IMT was made in 2002, when the Likangala irrigation scheme was selected for rehabilitation by the Ministry of Agriculture, Irrigation and Water Development. According to Nkhoma and Mulwafu (2004), progress was slow because of: insecure funding; a lack of management training for farmers; a water users' association or cooperative had not yet been established; the assumption that farmers would provide free labor in rehabilitation works; and rehabilitation work had to be scheduled around the wet season cultivation when farmers toil in their fields. Not only were there difficulties with funding, but building materials were stolen, farmers' cultivation schedules were interrupted, and the transfer process was not clearly communicated. Another major obstacle to the transfer was the misunderstanding of who owned the scheme (Nkhoma & Mulwafu, 2004). This is a common struggle; Nkhoma and Mulwafu (2004) state that village heads, well-off farmers, and poor farmers all tend to see the handover as an opportunity to reclaim what they perceive as rightfully theirs. This climate of uncertainty demoralizes farmers and feeds conflict that, because of cultural precedence, ends up being resolved by village heads rather than the scheme committees (Nkhoma & Mulwafu, 2004).

This paper elicits the willingness of smallholder farmers to invest capital and unpaid labor in the construction, maintenance, and management of four types of irrigation schemes, and explores determinants of the preferences. The specific objectives of the study are outlined in Section 2 and the study area is described in Section 3. Section 4 provides the methodologies of the survey and the econometric analysis. Section 5 gives results of the descriptive statistics, the willingness to invest questions, and the regression models. Finally, results are discussed and conclusions are drawn in Section 6.

2.2 Objectives

This study forms a part of the International Food Policy Research Institute's (IFPRI) project, "Policies and Institutions for Achieving the Virtuous Food-Energy-Water Nexus in Sub-Saharan Africa", which is funded under a research grant by the German Ministry of Development and Economic Cooperation (BMZ). Smallholder irrigation reform policies, including IMT, are encompassed by the food-energy-water nexus framework as each part of the nexus has direct and indirect effects on the other nodes of the nexus (Nielsen et al., 2015). Support for this study, provided by IFPRI and the University of Hohenheim, is gratefully acknowledged.

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.

2.3 Study Area

Dedza District lies between Lake Nyasa, the Mozambican border, and the national capital, Lilongwe, in Malawi's Central Region. The Kirk Range is a watershed plateau that runs north-south through Dedza and provides the district with great biophysical variety. The eastern side of the plateau descends into the Rift Valley, where Lake Nyasa is located at about 500m.a.s.l. The warm climate of the lakeshore allows for the cultivation of paddy rice, tobacco, and cotton. The western side of the plateau is much higher in elevation; the capital of the district, Dedza Township, is located there at 1590m.a.s.l. The subtropical highland climate of the west is conducive to the

farming of potatoes and groundnuts. During the dry season, usually from May to October, there is almost no precipitation, but several perennial rivers provide water for home consumption and irrigation.

In Malawi, beneath the municipal level of a district are Traditional Authority Areas (TAs). Dedza District is divided into eight TAs, each of which are further divided into Sections and then villages. The agricultural extension service is not perfectly aligned with the municipal structure. Beneath the District Agricultural Development Officer are Extension Planning Area officers. Extension Planning Areas may contain more than one TA and a large TA may be handled by more than one Extension Planning Area. Extension Planning Areas are divided into sections, each of which has an officer. Section officers are responsible for providing agricultural extension services to the villages in their section. Section officers are on the frontlines and report back to their Extension Planning Area officer regularly.

2.4 Methodology

2.4.1 Survey Methodology

The 300 smallholder farming households in Dedza District were sampled using stratification of randomization (Carletto, 1999). 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 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. Sections of the survey instrument included: crop management; irrigation practices and preferences; non-crop income; a hypothetical cash transfer program; dietary diversity; fuel use and access; self-assessed risk preference; time labor allocation; intra-household decision making; cookstoves and health; social capital; and access to credit. Preferences for different cookstove attributes and for different forms of a conditional subsidy were elicited through choice experiments. Sections of the questionnaire that are relevant to this thesis can be found in Appendix E.

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[2] (treadle pump, 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 (Blumenschein, Blomquist, Johannesson, Horn, & Freeman, 2008; Damschroder, Ubel, Riis, & Smith, 2007; Hensher, 2010; Murphy, Allen, Stevens, & Wheatherhead, 2005). 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 (Murphy et al., 2005). 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.

[2] The four irrigation technologies are depicted in Figures A1-A4 of the Appendices.

2.4.2 Econometric Methods

To investigate socio-economic determinants of respondents' willingness to invest in hypothetical irrigation schemes, ordinary least squares (OLS) regression analyses were conducted. Statistical analyses were done using statistical software, STATA Version 13. 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 24 investment 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.

The 12 explanatory variables were chosen for the theoretical likelihood that they would impact farmers' willingness to invest in an irrigation scheme. The percent of household members that are working age males (between the ages of 18 and 60) shows the labor endowment of the household; households with more available labor are expected to be willing to invest more toward irrigation scheme construction, maintenance, and management. The household social network score variable is a summation of organization membership and the ability to borrow from informal sources. The higher the social network score, the higher the household's social capital. Households with strong social networks are hypothesized to be willing to invest more in an irrigation scheme given their community involvement and mutual trust. The per capita household net income variable represents income from all possible sources, including crops sold, livestock sold, forestry, hunting, wage labor, aid, retirement payments, and remittances. Households with a higher per capita net income may have an amount of disposable income that they would be willing to invest in an irrigation scheme. Those households with a higher per capita number of cultivated land parcels and those households with more hectares of cultivated land per capita are expected to be interested in more effective irrigation that would reduce the strain on their labor capital.

Households with a lower average distance from field to market are hypothesized to be willing to invest more in an irrigation scheme because improved irrigation would lead to higher yields that they could easily sell at a nearby market. Elevation is expected to negatively affect a household's willingness to invest in an irrigation scheme, as farms at higher elevations experience lower average temperatures and more rainfall, lessening their need for improved irrigation. If the household's main agricultural decision maker has completed a higher level of formal education, is female, or perceives themselves as willing to take more risks, this person is hypothesized to be willing to invest more. Women are responsible for bucket watering crops, an intensive, cumbersome task, so female respondents are expected to be interested in investing in a more efficient irrigation technology. Respondents who see irrigation as important to their yields are predicted to be willing to invest more. The access to credit score is a composite of responses about the ability to acquire loans of different amounts from formal and informal sources. Because investing in an irrigation scheme uses up savings, households with better access to loans are expected to be more willing to draw from their savings and invest in a scheme.

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 is 1.29, indicating multicollinearity is not an issue (Chatterjee, Hadi & Price, 2000). Model specification was checked with the Ramsey Regression Specification Error Test. After the models failed the Breusch-Pagan test for heteroscedasticity, the regressions were re-run using estimates of robust standard errors (Rogers, 1993; Williams, 2000).

2.5 Results

2.5.1 Descriptive Statistics

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.[3] 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

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

education, 27% have completed the first four years of primary school, and 15% have completed all eight years of primary school.

In this study, a distinction is made between a household head and its main agricultural decision maker. For 89% of the respondent households, they are one and the same. The main agricultural decision makers in the other households are the wife (monogamous) of the household head (4%), the son of the household head (2%), the husband of the household head (2%), and the wife (first or second polygamous) of the household head (2%). Given the large percentage of household heads that are also main agricultural decision makers, the demographics of the two are almost identical.

All respondents are smallholder farmers; on average they operate 1.15 hectares of land. Farmers' land is divided into three parcels on average with the majority (84%) dedicated to the cultivation of crops. Land has mostly been received as a gift or inherited (85%), though some respondents lease land for a fixed payment (7%) and others have been granted access to land by local leaders (5%).

In order to make inferences about the importance of infrastructure to farmers' livelihoods, respondents were asked about the distance from their parcels to roads, markets, and irrigation sources. The results were positively skewed by the inclusion of extremely remote villages in the sample, therefore, in Table 2.1, both means and 50th percentiles are provided.

Table 2.1:

Average Distance from Cropland Parcel to Resource

Nearest	Mean *(in walking minutes)*	50th percentile *(in walking minutes)*
All-weather road	29	15
Seasonal road	27	10
Crop market	95	70
Dry season irrigation source	33	10
Rainy season irrigation source	29	10

Source: Own survey, 2014, Stata output

Dedza District is renowned among Malawians for its production of Irish potatoes, groundnuts, and beans. This is reflected in the respondents' reporting of their crop cultivation. Beans are grown by 49% of respondent households, groundnuts by 46%, soy by 39%, and Irish potatoes by 14%. However, as in the rest of Malawi, maize is the main crop in Dedza; 98% of

respondents grow maize. Malawians consider maize to be almost synonymous with food; a maize porridge called *nsima* dominates the national diet. Informal interviews repeatedly showed that Malawians without *nsima* would consider themselves to be food insecure, even if other food sources were abundant. This cultural belief has wide-reaching effects on nutrition security and agricultural policy.

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 being the most-used technology (on 11% of all plots), followed by gravity-fed canal irrigation (5%), bound basin (2%), treadle pumps[4] (1%), and motorized pumps (0.3%). Plots that are irrigated receive a watering an average of 14 times per month during the dry season and five times per month during the rainy season. 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.

2.5.2 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 Tables 2.2 and 2.3.

[4] 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.

Table 2.2:

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, Stata output

Table 2.3:

Willingness to Invest Capital

	To Construction *(USD[5])*	To Maintenance *(USD per year)*	To Management *(USD per year)*
Motorized Pump	8.58	5.42	4.51
Treadle Pump	9.03	6.32	4.51
Canal	2.71	1.81	1.35
Bound basin	0	0	0

Source: Own survey, 2014, Stata output

In Tables 2.2 and 2.3, 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

[5] 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 (OANDA, 2015). The average purchasing power parity adjusted for inflation was 1 USD was equal to 110.78 MWK during that same time (NSO, 2015; OANDA, 2015; The World Bank, 2015).

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.

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.[6]

2.5.3 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 (Ramsey RESET), 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; 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 2.4. Full results from all of the regression analyses are shown in Tables A1-A22

[6] 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).

of the Appendices. The regression tables show 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.

Table 2.4:

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 labor in 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

*, **, *** indicate statistical significance at the 10%, 5%, and 1% level, respectively.
Source: Own survey, 2014, Stata output

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 oversimplification. 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 (see Tables A17-A22). Similarly, there are only 210 observations for canal models (see Tables A11-A16). Because of the low number of observations, none of the bound basin models are statistically significant.

2.6. Discussion and Conclusions

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. 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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3. Should Malawi consider changing its fertilizer subsidy to a cash transfer? Stated preferences and policy recommendations

Emily McNulty, Thea Nielsen and Manfred Zeller

3.1 Introduction

Well-targeted fertilizer vouchers increase food production without crowding out commercial fertilizer. Unlike universal fertilizer subsidies, which lower fertilizer prices for all and thus harm the private sector, targeted programs give vouchers only to those who cannot afford market prices and would not otherwise be part of the fertilizer market (Ricker-Gilbert, Jayne, & Chirwa, 2011). Demand grows, retailers accept coupons from their new customers, and then retailers exchange the coupons with the government for the outstanding amount (Ricker-Gilbert et al., 2011). Farmers gain access to fertilizer and use it to increase their yields, and national food security is improved. This is how Malawi's Farm Input Subsidy Program (FISP) is designed to work, but because of numerous implementation issues, its success in terms of pro-poor development is contested. Stakeholders are seeking out alternatives, including conditional cash transfer (CCT) programs.

The history of the FISP is summarized in a Future Agriculture's policy brief by Blessings Chinsinga (2008). After a series of input support programs in the 1990s and early 2000s, the ruling United Democratic Front government launched the Extended Targeted Input Program (ETIP) in August of 2005, promising 26 kg of fertilizer and 5 kg of seeds to approximately 2.8 million farmers (Chinsinga, 2008). The announcement of the program was met with great expectation by stakeholders, but the delay in its implementation had a strong negative impact on yields from the 2004/2005 agricultural year (Chinsinga, 2008). Because of the untimely placement of orders with the private sector, there was a lack of supply. The distribution of the inputs was so late that the crucial period for fertilizer application had already passed and the inputs were largely useless (Chinsinga, 2008). A severe drought compounded the yield problem, and the 2005 food crisis ensued. As the ETIP had failed, foreign donors withdrew their support for it, their main criticisms being that: the very poorest, who could not make full use of the subsidy, were targeted; administrative and targeting costs were too high; targeting was ineffective; and the input market was being distorted by the subsidy (Chinsinga, 2008). The creation of the FISP in 2005 did not resolve all of these issues, but it did improve targeting. Coupons were introduced as a means of limiting the cost of the program and ensuring equitable distribution among recipients (Chinsinga, 2008). With a restricted number of coupons, households could only buy a certain amount of

fertilizer at the subsidized rate, any amount beyond that would have to be purchased at the prevailing market price.

The level of success that the FISP has achieved has proven difficult to quantify in the literature, as the budget burden, the net impact, and the targeting efficacy are estimated and weighed against each other. The budget for the 2005/2006 FISP was set at about 35 million USD, but grew to approximately 53 million USD during implementation, despite the fact that the amount of fertilizer actually distributed was only equal to about 75% of all of the coupons issued, the remaining coupons were not exchanged (Chinsinga, 2008). In that 2005/2006 fiscal year, approximately 8.3% of the total national budget was taken up by the FISP (Chinsinga, 2008). The following agricultural year, when donor funding resumed, the total cost of the FISP grew to 91 million USD (Dorward, Chirwa, Boughton, et al., 2008). From the beginning of the FISP, the program cost has been between 5% and 16% of Malawi's GDP (Pauw, Ecker, & Mazunda, 2011). The benefit-cost ratio of the 2006/2007 FISP is estimated between 0.76 and 1.36, not including secondary growth effects (Dorward, Chirwa, Boughton, et al., 2008), where a score greater than 1 indicates that the benefits outweigh the costs of the program. The wide spread in the benefit-cost ratio estimate is due to approximations in the following contributing factors: the sum of sales that would have been made at full price had farmers not received the subsidy; the extent of impact of other yield-affecting variables, including rainfall, timing of fertilizer application, and maize variety; accurate coupon targeting; and the extent to which additional maize yield lowers market prices and thus benefits maize purchasers, but may harm maize sellers (Dorward, Chirwa, Boughton, et al., 2008).

Maize production estimates given by the Ministry of Agriculture and Food Security seem to illustrate positive yield impacts resulting from the FISP: 1.2 million tonnes in 2004/2005 improved to 2.7 million tonnes in 2005/2006, and then to 3.4 million tonnes in 2006/2007 (Dorward, Chirwa, Boughton, et al., 2008). As the maize and tobacco sectors together make up about 15% of Malawi's GDP, these yield increases have powerful economic effects (Pauw et al., 2011). Farmers who did self-assessments of their economic wellbeing in May/June 2007 reported being 8% better-off than they were in 2004 (Dorward, Chirwa, Boughton, et al., 2008; Dorward, Chirwa, Kelly, et al., 2008). In the same period, reports of households experiencing a severe food price shock decreased from 79% to 20% (Dorward, Chirwa, Kelly, et al., 2008). However, if the failure of the FISP's predecessor,

the ETIP, can be partly blamed on the drought of 2005, then it follows that the apparent success of the FISP can be partly attributed to good rains in subsequent years. The fortuitous coincidence of the FISP with favorable rains is cited in the literature as a reason to be skeptical of the true utility of the program (Dorward, Chirwa, Boughton, et al., 2008; Dorward, Chirwa, Kelly, et al., 2008).

Although the poor and vulnerable are the intended targets of the FISP, several studies have found that they are not the primary beneficiaries (Chibwana, Fisher, Jumbe, Masters, & Shively, 2010; Chibwana, Fisher, & Shively, 2012; Dorward, Chirwa, Kelly, et al., 2008; Holden & Lunduka, 2010). Female-headed households are one of the vulnerable groups targeted by the FISP, but they are less likely to receive fertilizer coupons than male-headed households, and asset-poor households are less likely to receive fertilizer coupons than better-off households (Chibwana et al., 2010; Dorward & Chirwa, 2013; Holden & Lunduka, 2010; Ricker-Gilbert et al., 2011). Other groups who are less likely to receive coupons are the elderly (13% less likely) and those who consider themselves to be poor in a poverty self-assessment (8% less likely) (Chirwa, Matita, & Dorward, 2011).

In addition to ineffective targeting, the FISP's impacts on land allocation and crop simplification are cause for concern. Recipients of improved maize seed and fertilizer were found to have dedicated 45% more farm area to improved maize than non-recipients, which is positive for improved maize yield, but negative for crop diversity, especially given that those same farmers planted 17% less land with non-maize crops (Chibwana et al., 2012). The newly excluded crops were mainly groundnut, soy, cassava, and sweet potato (Chibwana et al., 2012). Cassava and sweet potato are inferior staples used as an alternative or supplement in the traditionally maize-focused Malawian diet. Losing diversity in staple crops could lead to food insecurity if the main crop, maize, has a poor harvest. Groundnut and soy are nitrogen-fixing legumes that improve soil fertility and provide a source of protein, dietary fiber, and micronutrients, to consumers (Messina, 1999; Temperton et al., 2007). The exclusion of legumes from farming systems is detrimental to the yields of other crops (Temperton et al., 2007), and their exclusion from human diets is damaging to nutritional health (Messina, 1999).

Modelling has shown the FISP to improve food security and caloric availability, but that improvements in calorie and micronutrient consumption slow down with broad-based economic growth (Ecker & Qaim, 2011; Pauw et al., 2011). Models for Malawi show that income

interventions, like cash transfers, are more effective than price interventions, like the FISP, at improving nutrition in terms of iron, zinc, vitamins A, B, and C, calories, and protein (Ecker & Qaim, 2011).

Crowding out of commercial goods is a threat when subsidies are implemented, and the case of the FISP is no exception. Fertilizer sales for the 2005/2006 agricultural year were significantly lower than in the previous year, and the private sector experienced serious losses, especially among small agricultural dealers (Dorward, Chirwa, Boughton, et al., 2008). Crowding out, or displacement, occurs when consumers who would ordinarily purchase a good at full market price instead purchase it at the subsidized price, and the value of the subsidy is essentially wasted. Displacement indicates a lack of effective targeting, and its existence subtracts from the net benefit of the subsidy. In the 2006/2007 agricultural year, full price fertilizer sales were crowded out by between 30% and 40% of fertilizer purchases with the FISP coupon (Dorward, Chirwa, Kelly, et al., 2008). Each additional kilogram of FISP fertilizer was found to displace 0.22 kg of market price fertilizer (Ricker-Gilbert et al., 2011). The displacement was, intuitively, lowest among the poorest recipients (0.18 kg), and highest among the better-off recipients (0.30 kg), reinforcing the knowledge that the subsidy's net effect will be maximized if it is accurately targeted to the poor (Ricker-Gilbert et al., 2011).

The full potential of the FISP is restricted by its untimely, opaque, and poorly-advertised implementation at all levels of the program (Holden & Lunduka, 2010). Farmers do not know how much fertilizer they can realistically expect to receive, so they are unable to properly plan their agricultural year, and they feel that the program is unfair. Agricultural extension agents and village development committees have been accused of diverting coupons, but few major cases have been proven (Dorward, Chirwa, Boughton, et al., 2008; Dorward & Chirwa, 2013). While diversion is probable, it is near impossible to quantify. A portion of the accusations may be due to farmers not knowing how much fertilizer they are entitled to in a given year (Dorward & Chirwa, 2013). If they knew their allotted amount in advance feelings of discontentment could be avoided and they could make financial and agricultural plans accordingly (Dorward & Chirwa, 2013). The assignment of coupons in open forums at the village level, followed by the distribution of coupons in village meetings increases the likelihood that poorer households will receive the coupons, and ensures fairness in the allocation process (Chirwa et al., 2011; Dorward & Chirwa, 2013).

Currently, most FISP recipients are targeted at the village level by traditional leaders (Dorward & Chirwa, 2013). While village heads are generally familiar with the economic status of their constituents, and making them responsible for coupon allocation does not affect the program budget, their targeting can be unfair (Dorward & Chirwa, 2013). Houssou and Zeller (2011) suggest a wealth and income proxy-based targeting system that would be more effective, in terms of both cost and accuracy, than the community-based targeting system. The indicator-based targeting would get 73% of the subsidy to the intended targets, a vast improvement on the 2006/2007 FISP that reached only 50%, and it would reduce leakage to the non-poor by more than half (Houssou & Zeller, 2011).

Another significant criticism of the FISP is that it focuses too narrowly on fertilizer dissemination. In the 2008/2009 agricultural year, a FISP coupon holder could buy 50 kg of fertilizer at 8% of the commercial price, and could receive 2 kg of improved maize seed for free (Chibwana et al., 2010). That means that beneficiaries of the FISP had a 25 to 1 ratio of fertilizer to improved seed, while the correct usage in most regions of Malawi is 5 kg of fertilizer for every 1 kg of improved maize seed (Chibwana et al., 2010). Because improved seed packets are significantly cheaper than sacks of fertilizer, and because improved maize varieties have larger yields than traditional varieties, balancing the fertilizer-seed ratio of the subsidy would make the program more cost effective (Chibwana et al., 2010). Focus group discussions done in preparation for this study show that smallholder farmers are interested in inputs other than fertilizer.

Given the numerous flaws of Malawi's FISP and the fact that it consumes 70% of the nation's agricultural budget (Douillet, 2012), it is worth exploring alternatives, specifically a conditional cash transfer (CCT) program. Following the well-documented success of Mexico's PROGRESA begun in 1997, and Brazil's Bolsa Familia begun in 2003, CCTs spread across Latin America and much of the world and are now active in more than 29 developing countries (Baird, Mcintosh, & Özler, 2011; Davis, Gaarder, Handa, & Yablonski, 2012; Kapur, 2011; The World Bank, 2009). CCTs have several advantages over subsidies: through conditionality they can be self-targeting, they are cost effective, and they do not distort market prices (Kakwani, Soares, & Son, 2005). The conditionality of CCTs also serves to address underinvestment in sectors that the market has failed, like education and health (Baird et al., 2011), or in the case of Malawi, forestry. Conditionality makes CCTs more attractive to non-poor stakeholders who would otherwise see the

intervention as a handout that would not benefit them (Baird et al., 2011; The World Bank, 2009). Delivering cash to the poor removes the paternalistic aspect of aid, allowing recipients to decide what is best for themselves, and relieving policy makers of the task of determining the most beneficial form of assistance (Kapur, Mukhopadhyay, & Subramanian, 2008). CCTs are set apart from other economic interventions because their duality allows them to have both short- and long-term impacts (Kakwani et al., 2005). The delivery of cash affects recipients' short-term wellbeing by satisfying immediate needs like food purchases, and the condition affects recipients' mid- and long-term wellbeing by meeting ongoing needs like school attendance and health check-ups (Kakwani et al., 2005).

Targeting recipients and confirming that they have met the conditions can make CCTs expensive; both determine not only the cost of the program but also its effectiveness (Kakwani et al., 2005). Although CCTs can be pricey, they are not necessarily more expensive than subsidies of the same scope. For example, if the value of India's budget for food, fertilizer, and fuel subsidies were divided equally among the country's 70 million poor households, the monthly transfer would raise those households above the rural poverty line (Kapur et al., 2008). Additionally, CCT programs become less expensive with time. During the first year of Mexico's PROGRESA, 1.34 USD was spent for every 1 USD of cash transfer, but by the third year most of the program's fixed costs had been settled and only $0.05 USD was spent for every 1 USD of cash transfer (Kapur et al., 2008).

Unlike subsidies, whose goods may not be appealing to non-poor households, cash is desired by poor and non-poor, so elite capture is a threat to CCTs. To prevent elite capture, a CCT program should be advertised clearly to its beneficiaries to inform them of how large of a cash transfer to expect (Kapur et al., 2008). The use of biometrics to identify beneficiaries and confirm their receipt of cash is optimal when there is no reliable identification card system in place (Kapur, 2011). When a biometric registry was begun in Andhra Pradesh, India, it was discovered that 12% of beneficiaries of a social transfer program did not exist, they were false identities created to steal the transfers (Kapur, 2011).

As CCT programs expand into Africa, unique challenges arise. Southern Africa has high HIV/AIDS prevalence, as well as unstable markets and political systems, that contribute to economic risk and vulnerability (Davis et al., 2012). Further, the heavy donor presence in southern Africa slows advancements in policy, such as the introduction of a CCT program. In 2014, Malawi

received over 930 million USD of official development assistance and official aid, representing 15.8% of its GNI that year (The World Bank, 2016a, 2016b). The demands and oversight of those foreign donors, combined with the political belief systems and power relationships of both donors and the government, congests and complicates the policy making process (Aberman et al., 2012; Chinsinga, 2007; Davis et al., 2012). However, the documented success of domestic pilot programs will hopefully assuage donor fears and convince them of the merits of CCT programs. Impact evaluations of the Malawi Social Cash Transfer program show it has increased the investment of recipients in agricultural assets, reduced child labor, and sustained children's school attendance (Boone, Covarrubias, Davis, & Winters, 2013; Covarrubias, Davis, & Winters, 2012; Davis et al., 2012).

It is not only the preferences of policy makers that affect CCT program development, but also the preferences of potential beneficiaries. Focus group discussions during the inception phase of this study indicated that smallholder farmers were dissatisfied with the FISP and would be open to a CCT program. According to focus group discussions conducted in five villages in Dedza District in June and July of 2013, the circulated FISP coupons are insufficient. Village heads must go to a FISP distribution point to collect their village's allotted coupons. When they return to the village the coupons are distributed among the households. A shortage of coupons was reported by all; some focus groups reported unfair, politically motivated coupon distribution, while others reported sharing coupons equally among all households. After receiving their coupons, farmers must travel to the nearest Agricultural Development and Marketing Corporation (ADMARC) to exchange their coupons for fertilizer. Those who do not use their FISP coupons reported selling them to other farmers. Given the problems associated with the FISP, farmers in the research area were open to alternatives.

This paper elicits the preferences of smallholder farmers for a hypothetical CCT over a fertilizer subsidy using a choice experiment, and explores determinants of the preferences. The specific objectives of the study are outlined in Section 2 and the study area is described in Section 3. Section 4 provides the methodologies of the survey, the choice experiment, and the econometric analysis. Section 5 gives results of the descriptive statistics, the choice experiment, the hypothetical expenditure question, and the regression models. Finally, results are discussed and conclusions are drawn in Section 6.

3.2 Objectives

With the aim of exploring alternatives to the FISP, this study determines smallholder farmers' preferences for a CCT over a fertilizer coupon, both of which are hypothetical and conditional on the adoption of easily verifiable agroforestry activities. A choice experiment is used to elicit the preferences, survey questions investigate bias against the CCT as well as uses for the CCT, and regression models provide insight into which socio-economic characteristics influence the preferences. The use of these methods make this study a unique contribution to the literature. Four research questions are addressed:

(1) Do farmers generally prefer the CCT or the fertilizer subsidy?

(2) Among farmers who never prefer the CCT, why do they always prefer the fertilizer subsidy?

(3) If farmers were to receive a CCT of 380 USD,[7] how would they spend the money? How do responses differ between the main agricultural decision maker and their spouse?

(4) Which socioeconomic factors affect preferences for the CCT or the fertilizer subsidy?

3.3 Study Area

Dedza District lies between Lake Nyasa, the Mozambican border, and the national capital, Lilongwe, in Malawi's Central Region. The Kirk Range is a watershed plateau that runs north-south through Dedza and provides the district with great biophysical variety. The eastern side of the plateau descends into the Rift Valley, where Lake Nyasa is located at about 500 m.a.s.l. The warm climate of the lakeshore allows for the cultivation of paddy rice, tobacco, and cotton. The western side of the plateau is much higher in elevation and holds the capital of the district, Dedza Township, which is 1,590 m.a.s.l. The subtropical highland climate of the west is conducive to the farming of potatoes and groundnuts. During the dry season, usually from May to October, there is almost no precipitation, but several perennial rivers provide water for home consumption and irrigation.

[7] 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 (OANDA, 2015). The average purchasing power parity adjusted for inflation was 1 USD was equal to 110.78 MWK during that same time (NSO, 2015; OANDA, 2015; The World Bank, 2015).

3.4 Methodology

3.4.1 Survey Methodology

The 300 smallholder farming households in Dedza District were sampled using stratification of randomization (Carletto, 1999). 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 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 300 households, which were representative of Dedza District, were interviewed in May and June of 2014. The survey coincided with the maize harvest, so preference for fertilizer may have been inflated by the impending need for it during the upcoming planting season.

The household survey was comprised of two parts: general survey questions and choice experiments. The survey questions covered demographics, livelihoods, and socioeconomic traits. The first choice experiment elicited preferences for improved cook stove attributes, and the second choice experiment, the topic of the present study, elicited preferences for a hypothetical CCT or a fertilizer coupon. Sections of the questionnaire that are relevant to this thesis can be found in Appendix E.

3.4.2 Choice Experiment Methodology

The subsidy choice experiment consisted of seven choice sets, each with two alternatives. Respondents were offered the two alternatives in one choice set after another, and asked to choose their preferred alternative. Table 3.1 shows the choice sets and corresponding alternatives.

Table 3.1:

Subsidy Choice Experiment

	Alternative 1: Cash Payment		Alternative 2: Fertilizer Coupon	
Choice Set	*Cash in MWK*	*Value in USD*[8]	*Kg of NPK*	*Value in USD*
1	20,000	50	75	50
2	20,000	50	100	70
3	20,000	50	150	105
4	28,000	70	100	70
5	28,000	70	150	105
6	36,000	90	100	70
7	36,000	90	150	105

Source: Own survey, 2014

The cash payment choice alternatives were given in the local currency, Malawian kwacha (MWK). The fertilizer coupon choice alternatives were given in kilogram amounts, easily visualized as the sacks that commonly contain 50kg of fertilizer. For example, in Choice Set 1, a coupon for 75kg of fertilizer is offered; a respondent would readily recognize this as one and a half sacks of fertilizer. NPK, a three-component fertilizer consisting of nitrogen, phosphorus, and potassium, was chosen as the type of fertilizer for the hypothetical subsidy because it is widely used in the study area. At the time of the study, one 50-kg bag of NPK sold for approximately 35 USD on the free market, without a FISP coupon.

The US dollar values given in Table 3.1 are for illustration purposes, they were not used during the execution of the choice experiments. The US dollar values show that the difference in monetary value between Alternative 1 and Alternative 2 varies from one choice set to the next. Choice Set 6 is the only choice set in which the cash payment is worth more than the fertilizer coupon, and despite being seemingly illogical, was included to reveal intense preference either against CCTs or for fertilizer coupons. Other than presenting the alternatives, during the individual choice experiments no guidance was given and discussion was strictly limited to brief reiterations of the choice experiment directions. For each choice set, respondents were simply asked, "Would you prefer a cash payment of ___ kwacha or a fertilizer coupon for ___ kg of NPK?"

[8] The US dollar values in Table 1 are equivalent to the Malawian kwacha values at the time of the survey (OANDA, 2015) and are not adjusted for purchasing power parity.

The subsidy choice experiment was preceded by a careful introduction. Upon arrival in each sampled village, the pre-selected respondents were gathered for a meeting. It was explained that both types of subsidy, the CCT and the fertilizer coupon, were hypothetical. The CCT could be spent on any item of the respondents' choosing, including but not limited to fertilizer, other inputs, non-agricultural goods, school fees, and medicine. It was also explained that both of the subsidies were conditional upon the adoption of agroforestry, then a description of agroforestry was given, including the costs and benefits of adoption, and how agroforestry practices would be verified in exchange for the subsidy. Great care was taken to emphasize that the fertilizer coupon was hypothetical and had nothing to do with the FISP. Because the FISP has so many issues with fair distribution, an untainted fertilizer program was needed for comparison with the CCT, so the hypothetical and conditional fertilizer coupon was created.

3.4.3 Econometric Methods

To investigate socio-economic determinants of respondents' preferences for the CCT over the fertilizer subsidy, logistic regression analyses were performed. Statistical analyses were done using statistical software, STATA Version 13. Regressions were run for all seven choice sets, using three independent variables: per capita household net income, elevation of the household, and gender of the main agricultural decision maker. Seven other independent variables were eliminated in the early stages of the model design because they were consistently statistically insignificant. These variables were social network score, per capita hectares of land cultivated, risk self-assessment score, access to credit score, amount of chemical fertilizer applied to plots, fertility management score, and eligibility for FISP (NPK coupon). The percent of household members that are working age males was removed from the models because although it was statistically significant in two of the models, it did not pass the Spearman's correlation test or the Kendall's tau correlation test (Hamilton, 2009). Following each regression analysis, diagnostic tests were run on the models that were statistically significant as a whole. The full models all passed the likelihood ratio test (Vuong, 1989) at the 10% level of probability of error, and Akaike's Information Criterion (Akaike, 2011) and Bayesian Information Criterion (Posada & Buckley, 2004) results both showed that the models were well-fit.

Households with higher per capita net income are hypothesized to prefer the CCT over the fertilizer subsidy, because they are assumed to have graduated from reliance on crop production

only and be aspiring to venture into other business activities. Households located at higher elevations are also predicted to prefer the CCT over the fertilizer coupon more often; villages at high elevations in Dedza are remote and lack infrastructure and linkages to markets. Fertilizer coupons are assumed to be less popular in remote areas where the opportunity cost of traveling to a location to exchange the coupon for fertilizer would be too large. Remote households that receive a coupon may be unable to reach a fertilizer distribution point and would be left with the option of selling their coupon (likely at below its value) to a neighbor capable of incurring the transportation cost. Cash is expected to be preferred in high elevation villages because it can be spent more flexibly. Female main agricultural decision makers are hypothesized to prefer the CCT more often than their male counterparts because women are predicted to be more involved in income source diversification, as they are not traditionally the ones to apply fertilizer.

3.5 Results

3.5.1 Descriptive Statistics

Given the size and the geographical range of the sample, the survey 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.[9] Household heads have an average age of 47 years, most are male (72%) and have a primary occupation as crop production (83%). A slight majority (52%) of household heads have not completed any level of formal education, 27% have completed the first four years of primary school, and 15% have completed all eight years of primary school.

All respondents are smallholder farmers; on average, they operate 1.15 hectares of land. Farmers' land is divided into three parcels on average with the majority (84%) dedicated to the cultivation of crops. Land has mostly been received as a gift or inherited (85%), though some respondents lease land for a fixed payment (7%) and others have been granted access to land by local leaders (5%).

Dedza District is renowned among Malawians for its production of Irish potatoes, groundnuts, and beans. This is reflected in the respondents' reporting of their crop cultivation.

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

Beans are grown by 49% of respondent households, groundnuts by 46%, soy by 39%, and Irish potatoes by 14%. However, as in the rest of Malawi, maize is the main crop in Dedza; 98% of respondents grow maize. Malawians consider maize to be almost synonymous with food; a maize porridge called *nsima* dominates the national diet. Informal interviews repeatedly showed that Malawians without *nsima* would consider themselves to be food insecure, even if other food sources were abundant. This cultural belief has wide-reaching effects on nutrition security and agricultural policy.

3.5.2 Preference for CCT or Fertilizer Coupon

Farmers generally prefer the fertilizer coupon over the CCT. Only when the CCT value is 20 USD higher than the fertilizer coupon's value (Choice Set 6) do 50% of respondents prefer the CCT, in all other choice sets the fertilizer coupon is preferred by the majority of respondents. The results, shown in Table 3.2, indicate that respondents carefully considered the choice sets and selected logically.

Table 3.2:

Preference for CCT

Choice Set	*Amount of NPK (kg)*	*Value of NPK (USD)*	*Value of CCT (USD)*	*% of respondents that prefer the CCT over the fertilizer coupon*
1	75	50	50	32%
2	100	70	50	20%
3	150	105	50	15%
4	100	70	70	29%
5	150	105	70	18%
6	100	70	90	50%
7	150	105	90	25%

Source: Own survey, 2014, Stata output

The NPK cash value is shown here in Table 3.2 for convenience, but was not made available to the respondents during the survey. It was up to the respondents alone to recognize when CCT values were equal to or exceeded the fertilizer coupon values and selected accordingly, and the results show they did that well. Of all the choice sets, Choice Set 3 has the largest value spread: the CCT is worth 55 USD less than the fertilizer coupon. The fact that the smallest percent of respondents (15%) prefer the CCT in that case, and that the largest percent of respondents (50%) prefer the CCT in the most favorable case (Choice Set 6), shows that farmers understood the value

differences and revealed their preferences accordingly. The 15% of respondents that prefer the CCT even though it was worth 55 USD less than the NPK coupon either had calculated the fertilizer value incorrectly, or have a strong bias against the fertilizer subsidy.

Some farmers (11%) always prefer the CCT, while a larger group (43%) always prefer the fertilizer coupon. These polarized groups show that biases exist against both the CCT and the fertilizer coupon. The number of times the CCT was preferred out of the seven choice sets is broken down by percentage of respondents in Table 3.3.

Table 3.3:

Frequency of CCT Preference

Number of times the CCT was preferred, out of 7 choice sets	*Percent of respondents*
0	43%
1	15%
2	14%
3	6%
4	8%
5	3%
6	0%
7	11%

Source: Own survey, 2014, Stata output

Of the 300 respondents, 129 prefer the fertilizer coupon in every choice set. These respondents were asked a follow-up question to the choice experiment: "Why do you prefer a fertilizer subsidy over a cash transfer even when the cash transfer is worth significantly more?". The responses are summarized in Table 3.4. Respondents cited up to three reasons, which is why the sum of the percentages exceeds 100.

Table 3.4:

Major Reasons for Always Preferring the Fertilizer Coupon

Reason stated	*% of 129 respondents who never preferred the CCT*
Concerned cash will be spent on unnecessary items	88%
Prefer sticking to what is already experienced	30%
Concerned cash will be stolen	16%
Fertilizer is best for yield/food security	4%

Source: Own survey, 2014, Stata output

Cash being spent on unnecessary items is a major concern (cited by 88% of the respondents who preferred the fertilizer coupon in every choice set), suggesting either that there are intra-household budgeting issues (Handa & Peterman, 2009), or that respondents do not trust themselves to spend cash wisely. About one-third (30%) of the respondents who always prefer the fertilizer coupon did so because they are familiar with the concept of a fertilizer coupon because of the FISP. Theft of cash was also a concern (16%) because without banking or a secure place at home to store money, a CCT is risky.

3.5.3 Hypothetical CCT Expenditures

After the choice experiments were completed, respondents were asked to imagine that they had received a CCT of 380 USD. Both the main agricultural decision maker and their spouse, if applicable, were then separately asked how they would spend the cash. Table 3.5 shows the responses, with the main agricultural decision makers distinguished by gender.

Table 3.5:

Uses for Hypothetical Cash Transfer

Expense	*Percent of male main agricultural decision makers (n=215)*	*Percent of female main agricultural decision makers (n=85)*	*Percent of spouses (n=133)*
Fertilizer	55%	33%	43%
Own agricultural business***	18%	27%	27%
Livestock	6%	7%	3%
Food	3%	7%	4%
Other inputs	1%	1%	2%
Own non-agricultural business**	8%	7%	14%
Home improvements	6%	7%	5%
Clothing and shoes	0%	1%	0%
Hiring labor	0%	2%	0%
Education*	0%	2%	2%
Buying or renting land in	1%	1%	1%
Processing crops	1%	4%	1%

Source: Own survey, 2014, Stata output

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

Responses were quite similar between the male main agricultural decision makers, the female main agricultural decision makers and the spouses; all three groups highly value fertilizer and agricultural business. The Pearson's Chi-Square test and the Fischer's exact tests (Hamilton, 2009)

were run with the result that headship and hypothetical CCT spending plans are not independent of one another. At the 10% confidence level, the tests indicate that there is a relationship between whether a respondent is a male main decision maker, a female main decision maker, or a spouse and what the respondent plans to spend the CCT cash on. None of the respondents reported that they plan to spend the cash on cell phone expenses, gifts, vices, or repaying debt.

3.5.4 Socio-Economic Determinants of CCT Preference

A logistic regression was run for each of the seven choice sets in the choice experiment to find which socioeconomic characteristics are associated with a preference for the CCT. Five of the seven models were statistically significant as a whole, they are shown in Tables 3.6-3.10. The two models that were not statistically significant as a whole can be found in Tables B1 and B2 of the Appendices.

Table 3.6: Logistic Regression Results for Choice Set 1

Logistic regression	Number of obs	=	300
	LR chi2(3)	=	7.32
	Prob > chi2	=	0.0623*
Log likelihood: -184.4004	Pseudo R2	=	0.0195

Choice Set 1	*Odds Ratio*	*St. Err.*	*z*	*P>|z|*	*95% Confidence Interval*	
Net per capita income	.999997	.0006387	-0.53	0.596	.99841	1.000914
Elevation	1.001114	.0004658	2.39	0.017**	1.000202	1.002028
Gender of decision maker	.896451	.2437209	-0.40	0.688	.5261478	1.527374
Constant	.1324104	.0795649	-3.36	0.001	.0407792	.4299381

Source: Own survey, 2014, Stata output

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

In Choice Set 1, where 32% of respondents prefer the 50 USD CCT over the 50 USD-value fertilizer coupon, the preference for the CCT can be explained by the household's elevation. For an increase in a household's elevation by one meter, the odds that the household will prefer the CCT in Choice Set 1 are expected to increase by 0.1%.

Table 3.7: Logistic Regression Results for Choice Set 2

Logistic regression	Number of obs	=	300
	LR chi2(3)	=	9.71
	Prob > chi2	=	0.0212**
Log likelihood: -143.87003	Pseudo R2	=	0.0326

Choice Set 2	*Odds Ratio*	*St. Err.*	*z*	*P>|z|*	*95% Confidence Interval*	
Net per capita income	.9972507	.0015244	-1.80	0.072*	.9942674	1.000243
Elevation	1.000805	.0005501	1.46	0.143	.9997276	1.001884
Gender of decision maker	1.272027	.3907462	0.78	0.433	.6966601	2.322585
Constant	.1008374	.0719219	-3.22	0.001	.0249175	.408073

Source: Own survey, 2014, Stata output

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

In Choice Set 2, where 20% of respondents prefer the 50 USD CCT over the 70 USD-value fertilizer coupon, the preference for the CCT can be explained by a household's per capita net income. For each additional 1 USD of per capita net income, the odds that a household will select the CCT in Choice Set 2 decreases by 0.27%.

Table 3.8: Logistic Regression Results for Choice Set 3

Logistic regression	Number of obs	=	300
	LR chi2(3)	=	8.31
	Prob > chi2	=	0.0400**
Log likelihood: -122.65599	Pseudo R2	=	0.0328

Choice Set 3	*Odds Ratio*	*St. Err.*	*z*	*P>|z|*	*95% Confidence Interval*	
Net per capita income	.9967311	.0019364	-1.69	0.092*	.992943	1.000534
Elevation	1.000532	.0005906	0.90	0.368	.9993748	1.00169
Gender of decision maker	1.440448	.4846938	1.08	0.278	.7448667	2.785588
Constant	.0977395	.0748134	-3.04	0.002	.0218036	.4381384

Source: Own survey, 2014, Stata output

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

In Choice Set 3, where 15% of respondents prefer the 50 USD CCT over the 105 USD-value fertilizer coupon, the preference for the CCT can be explained by a household's net per capita income. For each additional 1 USD of per capita net income, the odds that a household will select the CCT in Choice Set 3 decreases by 0.33%.

Table 3.9: Logistic Regression Results for Choice Set 5

Logistic regression	Number of obs	=	300
	LR chi2(3)	=	8.80
	Prob > chi2	=	0.0321**
Log likelihood: -135.49104	Pseudo R2	=	0.0314

Choice Set 5	*Odds Ratio*	*St. Err.*	*z*	*P>|z|*	*95% Confidence Interval*	
Net per capita income	.9986313	.0011859	-1.15	0.249	.9963096	1.000958
Elevation	1.00117	.0006049	1.94	0.053**	.9999852	1.002356
Gender of decision maker	1.520007	.4830325	1.32	0.188	.8153579	2.83363
Constant	.0491936	.0389361	-3.81	0.000	.0104278	.2320721

Source: Own survey, 2014, Stata output
** indicates statistical significance at the 5% level.

In Choice Set 5, where 18% of respondents prefer the 70 USD CCT over the 105 USD-value fertilizer coupon, the preference for the CCT can be explained by a household's elevation. For an increase in a household's elevation by one meter, the odds that the household will prefer the CCT in Choice Set 5 are expected to increase by 0.1%.

Table 3.10: Logistic Regression Results for Choice Set 7

Logistic regression	Number of obs	=	300
	LR chi2(3)	=	8.05
	Prob > chi2	=	0.0450**
Log likelihood: -163.56721	Pseudo R2	=	0.0240

Choice Set 7	*Odds Ratio*	*St. Err.*	*z*	*P>|z|*	*95% Confidence Interval*	
Net per capita income	.9997771	.0007157	-0.31	0.755	.9983754	1.001181
Elevation	1.00099	.0005013	1.97	0.048**	1.000007	1.001973
Gender of decision maker	1.712614	.4856867	1.90	0.058*	.9823449	2.98576
Constant	.0841002	.0549941	-3.79	0.000	.0233446	.3029759

Source: Own survey, 2014, Stata output

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

In Choice Set 7, where 25% of respondents prefer the 90 USD CCT over the 105 USD-value fertilizer coupon, the preference for the CCT can be explained by the household's elevation and the gender of its main agricultural decision maker. For an increase in a household's elevation by one meter, the odds that the household will prefer the CCT in Choice Set 7 are expected to increase by 0.1%. Those households with a female main agricultural decision maker are 1.71 times more likely to select the CCT in Choice Set 7. Of all the choice sets, Choice Set 7 has the slightest negative value difference between the CCT and the fertilizer coupon. Female agricultural decision makers value the CCT just slightly over the fertilizer coupon.

3.6 Discussion and Conclusions

Respondents were found to generally prefer the fertilizer coupon over the cash transfer, because of concerns about how the cash would be spent and aversion to an unfamiliar program. The fear of the unknown could be resolved by a thorough advertising campaign, and would dissipate once recipients begin to enjoy the benefits of the program. The issue of intrahousehold financial control can be skirted with careful program design (Benderly, 2011), but has been found to have no effect on the increase in food expenditure that CCTs produce (Braido, Olinto, & Perrone, 2012).

The regression models show that a preference for the CCT can in some cases be explained by a lower household net income, a higher elevation, and a female main agricultural decision maker. The negative impact of an increase in household income on the preference for the CCT is slight in the regression models, but it is indicative. Although great care was taken to distinguish the hypothetical fertilizer coupon of the choice experiment from the current FISP coupons in circulation in Malawi, it is likely that respondents were biased by their experiences with the FISP. Studies have shown that FISP coupons are often unfairly distributed and can land in the hands of wealthier, and politically better-connected, households (Chibwana et al., 2010; Chirwa et al., 2011; Dorward & Chirwa, 2013). Possibly aware of this, the poorer households of the study were more interested in the CCT. With the improved targeting that is inherent to CCTs, and the use of proxy income indicators, a cash transfer program could reach the poorer households. Further, the imbalance in the research experiment, the comparison of a hypothetical and a known, could be

improved upon in future research. A CCT could be offered for a period of time leading up to a study, so that respondents may gain firsthand experience and be able to make well-informed decisions.

The preference for the CCT by respondents living at high elevations was clear in the regression models. In Dedza District, villages in mountainous areas are remote and have limited market access. The transaction cost of a fertilizer coupon is markedly higher for those with poor infrastructure and market access than for those in a central location. Fertilizer coupons must either be collected at a distributor, or delivered to recipients' villages, then they can only be used at certain agricultural dealers, and the heavy product must be transported home. These barriers make the CCT a more attractive subsidy to those in remote areas.

The regression model for Choice Set 7, in which the fertilizer coupon is worth just 15 USD more than the CCT, indicates that women's valuation of the CCT is just slightly higher than that of their male counterparts. As agricultural work is traditionally done by males, women are likely to pursue income from other avenues, for which they would need the type of untethered support that CCTs provide. However, the modest level of evidence suggests that female main agricultural decision makers take on farming responsibilities and are for the most part reliant on agriculture for income.

As previously mentioned, the main flaws of the FISP are the budget burden, the unproven benefits, and inadequate targeting. CCTs have been shown to be cost-effective (Kakwani et al., 2005; Kapur et al., 2008); a cash transfer program in Malawi would provide much needed budget relief to the government. There is well-documented success of numerous CCT programs in assisting the poor and beneficiaries can be effectively targeted (Baird et al., 2011; Davis et al., 2012; Kakwani et al., 2005; Kapur, 2011; The World Bank, 2009). The rapid deforestation from which Malawi suffers could be thwarted in the mid term and long term with the inclusion of agroforestry adoption as the conditionality in a cash transfer program. With careful planning, the replacement of the FISP with a well-targeted, transparent CCT program would allow Malawi to join the ranks of other developing countries that have reaped the rewards of shifting from price interventions to income interventions.

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4. SMALLHOLDER FARMERS' WILLINGNESS TO PAY FOR IMPROVED COOKSTOVES IN DEDZA, MALAWI

Emily McNulty, Thea Nielsen and Manfred Zeller

4.1 Introduction

As improved cookstove (ICS) programs increase in popularity, policy makers and entrepreneurs need accurate estimates of the target market's willingness to pay (WTP) for the stoves. Knowing which socioeconomic factors affect WTP will allow program planners to price and target the stoves effectively. This study elicits the WTP of rural Malawians for two types of ICS and explores the determinant socioeconomic factors.

The widespread use of biomass fuel for heating and cooking has strong negative impacts on human health and the environment. Biomass, mainly charcoal and wood, is the main cooking fuel for 2.7 billion people around the world (Bensch & Peters, 2012, 2013). In Sub-Saharan Africa, biomass is the primary fuel for 81% of the general population, and for close to 100% of the rural population (Bensch & Peters, 2012, 2013). The pollutants given off by the combustion of solid fuel are extremely harmful to human health, particularly when cooking is done indoors without adequate ventilation (Bruce, Perez-Padilla, & Albalak, 2002; Fitzgerald et al., 2012). Each year, 2 million deaths are attributed to household air pollution, which is more than the number of deaths caused by malaria, and makes cooking with biomass fuels the world's primary environmental cause of death (Bensch & Peters, 2012; Hanna, Duflo, & Greenstone, 2012; Martin II, Glass, Balbus, & Collins, 2011). The deaths occur when ailments like low birthweight, high blood pressure, acute lower respiratory infection, chronic obstructive pulmonary disease, and asthma are caused or worsened by the pollutants (Fitzgerald et al., 2012). Because women are generally responsible for preparing meals, and they tend to have their children nearby during cooking activities, women and children are most affected by indoor air pollution (Bensch & Peters, 2012; Fitzgerald et al., 2012; Jan, 2012). More than 50% of all premature deaths caused by household pollution occur in children under five years of age due to their vulnerability during critical growth stages (Fitzgerald et al., 2012; Rehfuess, Mehta, & Prüss-Üstün, 2006). Cooking with biomass fuels is not only harmful to women's health, but it also constitutes a heavy opportunity cost. Women in developing countries are commonly charged with the chore of household fuel acquisition. Collecting or purchasing charcoal and firewood can be very time consuming and often dangerous (Bensch & Peters, 2012). The inefficiency of biomass fuels also contributes greatly to deforestation through unsustainable firewood and charcoal production (El Tayeb Muneer & Mukhtar Mohamed, 2003) and to global

climate change through its removal of carbon sinks, and the release of carbon dioxide and black carbon during cooking (Hanna et al., 2012).

Widespread dissemination of ICS is seen by many to be a feasible and effective intervention to improve human health, promote gender equality, relieve pressure on forests, and mitigate climate change (Bensch & Peters, 2012; El Tayeb Muneer & Mukhtar Mohamed, 2003; Fitzgerald et al., 2012; Jan, 2012). The term ICS covers a broad range of stove technologies that are all an improvement on the traditional three-stone stove in terms of fuel efficiency and emissions. ICS can be made from clay, brick, or metal, and they have a form that to varying extents encloses the cooking fire. The most fuel efficient ICS models are almost entirely enclosed and have a chimney to transport smoke and fumes outside of the home. The less fuel efficient ICS models do not have a chimney, but are transportable to encourage outdoor cooking during favorable weather conditions. The different ICS models vary greatly in cost, and higher cost is generally correlated with higher fuel efficiency and emission reduction. Further studies establishing the exact benefits of various ICS models to air pollution and health are described by Bensch and Peters (2012) and Fitzgerald et al. (2012).

The first ICS dissemination programs were launched in the 1970s (Arnold et al., 2003). They were focused mainly on the deforestation mitigation effects of widespread adoption (García-Frapolli et al., 2010), and received relatively little policy attention (Jan, 2012). ICS programs recently reemerged in the policy spotlight, this time with the focus more on human health and women's empowerment (García-Frapolli et al., 2010; Ruiz-Mercado, Masera, Zamora, & Smith, 2011). The ICS trend gained a major foothold when in 2010, Hillary Clinton, who at the time was the United States Secretary of State, together with the United Nations Foundation, launched the Global Alliance for Clean Cookstoves (Bensch & Peters, 2012; Hanna et al., 2012; The Economist, 2010). The Alliance's goal is to have 100 million households adopt ICS by the year 2020. If ICS are priced appropriately and targeted effectively, production and demand may develop simultaneously in a way that is self-sustaining and allows the stoves to survive on the free market. Further, if ICS adoption can outgrow its subsidy-requiring stage, rural people in developing countries may not have to wait for the stoves to be on trend a third time to enjoy the benefits.

Despite the newfound attention to ICS programs and the potential of the stoves to combat an array of issues, their adoption and sustained use face several challenges. The benefits of an ICS

are not immediately apparent to the rural poor who, because of a lack of education, may undervalue the fuel saving and health improving traits of the stoves (Bensch & Peters, 2012; El Tayeb Muneer & Mukhtar Mohamed, 2003; Gill, 1987; Mobarak, Dwivedi, Bailis, Hildemann, & Miller, 2012). Understandably, poor households struggling to meet their most basic needs are not interested in a technology with a relatively high price and fairly abstract benefits (Mobarak et al., 2012).

There is also a marketing issue slowing ICS adoption. Given the harms of kitchen pollution, the labor hours spent collecting biomass fuels, and the prohibitive costs of cleaner fuels, the groups that stand to benefit the most from ICS adoption are the most vulnerable: women, children, and the poor (Jan, 2012). These groups also tend to have the least bargaining power and the least economic autonomy. Women are the primary stove users, but they are not generally empowered to make large purchases (Bensch & Peters, 2012; El Tayeb Muneer & Mukhtar Mohamed, 2003; Miller & Mobarak, 2011). Although the woman of a household may be interested in improving her respiratory health, as well as her children's, and limiting the amount of time spent collecting firewood, the male head of the household may not value those changes highly enough to make the purchase.

The improvements that ICS have the potential to achieve once adoption does occur are stunted by a common phenomenon called "stacking" (Ruiz-Mercado et al., 2011; Takama, Tsephel, & Johnson, 2012). Fuel stacking happens when a household adopts a new fuel source in addition to its current fuel source, rather than replacing the old fuel with the new, and the same can be done with stoves. A household with an ICS may revert to their three-stone stove when certain dishes require a distinct flavor, or when tradition calls for it, or simply when making multiple dishes at once. The maintenance required for many ICS models may cause adopters to revert entirely to their traditional stove (Hanna et al., 2012). A study by Hanna et al. (2012) found that ICS adopters did not experience any significant health or fuel use improvements in the long term, although they had during the first year of adoption, because they did not clean out the stoves' chimneys or otherwise maintain them and they fell into disrepair.

ICS are known as a "bridging technology" because they bridge the gap between the status quo of inefficient three-stone stoves and the ideal of universal clean fuel use and electricity grids (Bensch & Peters, 2012). ICS are a vast improvement on the three-stone stove, but because they

still require biomass for fuel they are not clean enough to meet the World Health Organization's emissions recommendations (Concern Universal, 2012). The enormous cost and task of providing access to clean energy and electricity to rural households is too much to take on at once, so policy makers settle for the bridging technology of the ICS.

There are few studies on the impacts of ICS adoption in Malawi, and none could be found on socioeconomic determinants of adoption in Malawi. One study modelled the adoption of institutional-scale ICS for use in school lunch programs and found that they had a net positive affect on the Malawian economy after ten years (Habermehl, 2008). With numerous agencies disseminating different ICS models throughout Malawi, there is no data on the current extent of ICS adoption available. The goal of Malawi's National Cookstove Taskforce, which started in 2013, is to have 2 million households adopt ICS by 2020 (US Department of State, 2014). The potential for ICS to benefit Malawians is enormous given that 91.4% of the population uses wood for cooking and 13,250 people die of household air pollution each year, 5,852 of whom are children (Global Alliance for Clean Cookstoves, 2016). The firewood savings attributed to ICS would also be of great benefit to Malawi as the deforestation rate is 2.8% per year due to human activities (Food and Agriculture Organization, 2016). Fuel savings would also translate into increased food security as firewood collectors would burn fewer calories performing the arduous task.

The two types of ICS in this study are a clay stove and a rocket stove. Figures C1-C3 of the Appendices show the traditional three-stone stove, the clay stove, and the rocket stove. The clay stove is called *chitetezo mbaula* in Malawi. It is made of locally-sourced fired clay and has an enclosed form. At the time of the survey, the clay stove was available for purchase in the research area at certain gas stations and supermarkets, as well as from NGOs promoting the stoves in some villages. The rocket stove is a gasifying metal stove made by a South African company called Rocket Works. The rocket stove is even more fuel efficient than the clay stove and at the time of the survey was unavailable in Malawi. Both stoves are more fuel efficient than the standard three-stone stove used throughout Dedza. The clay stove becomes hot to the touch when in use, while the rocket stove does not. The clay stove is heavy and will crack if dropped. When cool and not in use, the rocket stove can be turned on its end and used as a stool.

This paper elicits the willingness of smallholder farmers to pay for the clay stove and the rocket stove, and explores socioeconomic determinants of their WTP. The specific objectives of

the study are outlined in Section 2 and the study area is described in Section 3. Section 4 provides the methodologies of the survey and the econometric analysis. Section 5 gives results of the descriptive statistics, the willingness to pay questions, and the regression models. Finally, results are discussed and conclusions are drawn in Section 6.

4.2 Objectives

With the aim of informing future ICS program developers, this study explores which socioeconomic traits influence consumers' stated willingness to pay (WTP) for two types of ICS: a clay stove and a rocket stove. Findings are compared with those from studies done in other regions with different stoves (El Tayeb Muneer & Mukhtar Mohamed, 2003; Jan, 2012; Mobarak et al., 2012; Pine et al., 2011). The novelty of this study is that it is the only one to compare the socioeconomic determinants of WTP for the clay stove and the rocket stove in Malawi. Explanatory models are composed of independent variables including time spent acquiring fuel, fuel expenditures, household characteristics, social capital, dietary diversity, health indicators, and credit access.

Given the study's objectives, four research questions emerge:

(1) What is the average WTP for the clay stove?

(2) What is the average WTP for the rocket stove?

(3) Which socioeconomic characteristics influence a households' WTP for the clay stove?

(4) Which socioeconomic characteristics influence a households' WTP for the rocket stove?

4.3 Study Area

Dedza District lies between Lake Nyasa, the Mozambican border, and the national capital, Lilongwe, in Malawi's Central Region. The Kirk Range is a watershed plateau that runs north-south through Dedza and provides the district with great biophysical variety. The eastern side of the plateau descends into the Rift Valley, where Lake Nyasa is located at about 500 m.a.s.l. The warm climate of the lakeshore allows for the cultivation of paddy rice, tobacco, and cotton. The western side of the plateau is much higher in elevation and holds the capital of the district, Dedza Township, which is 1,590 m.a.s.l. The subtropical highland climate of the west is conducive to the farming of

potatoes and groundnuts. During the dry season, usually from May to October, there is almost no precipitation, but several perennial rivers provide water for home consumption and irrigation.

4.4 Methodology

4.4.1 Survey Methodology

The 300 smallholder farming households in Dedza District were sampled using stratification of randomization (Carletto, 1999). 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 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.

Villages with access to the clay stove were purposively omitted from the sample, however, five households that owned a clay stove were inadvertently included in the sample. These households had purchased their clay stoves from a business-minded agricultural extension officer. This extension officer had purchased a large number of stoves and at the time of the survey had just begun to sell the stoves during his field visits. No villages had access to the rocket stove.

Upon entering a village and before beginning the individual household interviews, respondents were gathered for a group meeting. It was emphasized that the availability of both ICS for purchase was purely hypothetical and that farmers' identities would remain confidential. The two ICS, namely, the clay stove and the rocket stove, were presented. Respondents were informed about the advantages and disadvantages of the stoves and how the stoves function. Respondents were also given the opportunity to handle the stoves and ask questions. Later, when the household interviews were done in private, respondents were asked how much they would be willing to pay for each type of stove. Sections of the questionnaire that are relevant to this thesis can be found in Appendix E. All survey respondents were present at their village's group meeting. The group meeting was led by the same enumerator using the same script in every village.

Given financial and temporal constraints, the 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 (Blumenschein, Blomquist, Johannesson, Horn, & Freeman, 2008; Damschroder, Ubel, Riis, & Smith, 2007; Hensher, 2010; Murphy, Allen, Stevens, & Wheatherhead, 2005). 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 WTP in the hope that their village would be chosen for an ICS program. ICS promoters should be aware of this possibility when determining the price at which to sell their stoves.

4.4.2 Econometric Methods

Ordinary least squares (OLS) regression analyses were performed to discover which socio-economic characteristics influence respondents' WTP for both types of stove. Statistical analyses were done using statistical software, STATA Version 13. Initially, both regression analyses contained 11 independent variables that were chosen based on the theoretical likelihood that they would impact WTP for an ICS. For both the clay stove and the rocket stove WTP models, the number of explanatory variables had to be greatly reduced to improve the models' statistical significance.

The original 11 independent variables were: per capita household income, credit access score, social network score, household size, cook's education, cook's age, cook's gender, sickness score, dietary diversity score, amount spent buying fuel, and time spent acquiring fuel. These variables and their hypothesized effect on WTP for an ICS are shown in Table 4.1.

Table 4.1:

Independent Variables

Variable Name	*Description*	*Mean (Median)*	*Hypothesized Impact on WTP*
Per capita HH income (USD)	Annual net household income from all sources	93 (0)	Higher income, higher WTP
Credit access score	Ability to acquire formal and informal loans of varying amounts, scored 0-10	1.3 (0)	Higher score, higher WTP
Social network score	Organization membership and informal borrowing, scored 0-20	7.7 (7)	Higher score, higher WTP
Household size	Number of permanent household residents	5.1 (5)	More members, higher WTP
Cook's education	Highest level of education completed by main person responsible for cooking, 0-14 years	2.4 (0)	More years of education, higher WTP
Cook's age	Age of main person responsible for cooking	40.2 (36)	Older, higher WTP
Cook's gender	Gender of main person responsible for cooking, 0=male, 1=female	1 (1)	Female, higher WTP
Sickness score	Burns, eye infections, and respiratory illness among household members, scored 0-8	0.9 (0.7)	Higher score, higher WTP
HH dietary diversity score	Sum of food groups consumed by household in 24 hours preceding interview, scored 0-12	5.4 (5)	Higher score, higher WTP
Amount spent buying fuel (USD)	Household fuel expenditure per month	4 (0)	Higher expenditure, higher WTP
Time spent acquiring fuel (minutes)	Time spent in week preceding interview purchasing or collecting fuel	190 (120)	More time spent, higher WTP

Source: Own survey, 2014, Stata output

The per capita household annual net income variable represents income from all possible sources, including crops sold, livestock sold, forestry, hunting, wage labor, aid, retirement payments, and remittances. Households with more income per capita are expected to be willing to pay more for an ICS, because they may have disposable income that they are willing to invest. The access to credit score is a composite of responses about the ability to acquire loans of different amounts from formal and informal sources. Because purchasing an ICS may use up savings, households with better access to loans are expected to be more willing to draw from their savings to purchase a stove. The household social network score variable is a summation of organization membership and informal borrowing ability, based on the concept that participation in community activities enriches social capital (Putnam, 1995). The higher the social network score, the higher the household's social capital. Those households with strong social networks are hypothesized to be willing to pay more for an ICS as their social nature may make them willing to try new technologies. Isham (2002) found this to be true in rural Tanzania in a study on the positive correlation between social capital and adoption rates of a new fertilizer. Households with relatively more members are also expected to be willing to pay more for an ICS because they may be interested in increasing the amount they can cook at once by having a more efficient stove or by adding an additional stove to their kitchen. If the household's main cook has completed a higher level of formal education, is female, or is older, the household is hypothesized to be willing to pay more. The sickness score is a composite of responses about cooking-related ailments, including burns, eye infections, and respiratory illness. Because of the health benefits associated with ICS adoption, households with higher sickness scores are expected to be willing to pay more to improve their household's overall health. The dietary diversity score is a sum of food groups consumed by household members within the 24 hours preceding the survey; the score ranges from 0 to 12. This study uses the 12 food groups set forth by the FAO's "Guidelines for Measuring Household and Individual Dietary Diversity" (Kennedy, Ballard, & Dop, 2010). Households with higher dietary diversity scores are hypothesized to be willing to pay more for an ICS, which would support their well-balanced diets by making slow-cook foods, like legumes, less costly to prepare. Households that spend more per month on fuel purchases were expected to be willing to pay more for an ICS as the fuel efficiency would off-set their fuel costs. Similarly, those households that spend more time acquiring fuel, whether purchasing or collecting, are expected to be willing to pay more.

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 factors are 1.03 and 1.05 for the clay stove model and the rocket stove model, respectively, indicating that multicollinearity is not an issue (Chatterjee, Hadi & Price, 2000). Model specification was checked with the Ramsey Regression Specification Error Test. After the models failed the Breusch-Pagan test for heteroscedasticity, the regressions were re-run with robust standard errors (W. H. Rogers, 1993; Williams, 2000).

4.5 Results

4.5.1 Descriptive Statistics

Given the size and the geographical range of the sample, the survey 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.[10] Household heads have an average age of 47 years, most are male (72%) and have a primary occupation as crop production (83%). A slight majority (52%) of household heads have not completed any level of formal education, 27% have completed the first four years of primary school, and 15% have completed all eight years of primary school.

All respondents are smallholder farmers; on average, they operate 1.15 hectares of land. Farmers' land is divided into three parcels on average with the majority (84%) dedicated to the cultivation of crops. Land has mostly been received as a gift or inherited (85%), though some respondents lease land for a fixed payment (7%) and others have been granted access to land by local leaders (5%).

Dedza District is renowned among Malawians for its production of Irish potatoes, groundnuts, and beans. This is reflected in the respondents' reporting of their crop cultivation. Beans are grown by 49% of respondent households, groundnuts by 46%, soy by 39%, and Irish potatoes by 14%. However, as in the rest of Malawi, maize is the main crop in Dedza; 98% of respondents grow maize. Malawians consider maize to be almost synonymous with food; a maize porridge called *nsima* dominates the national diet. Informal interviews repeatedly showed that

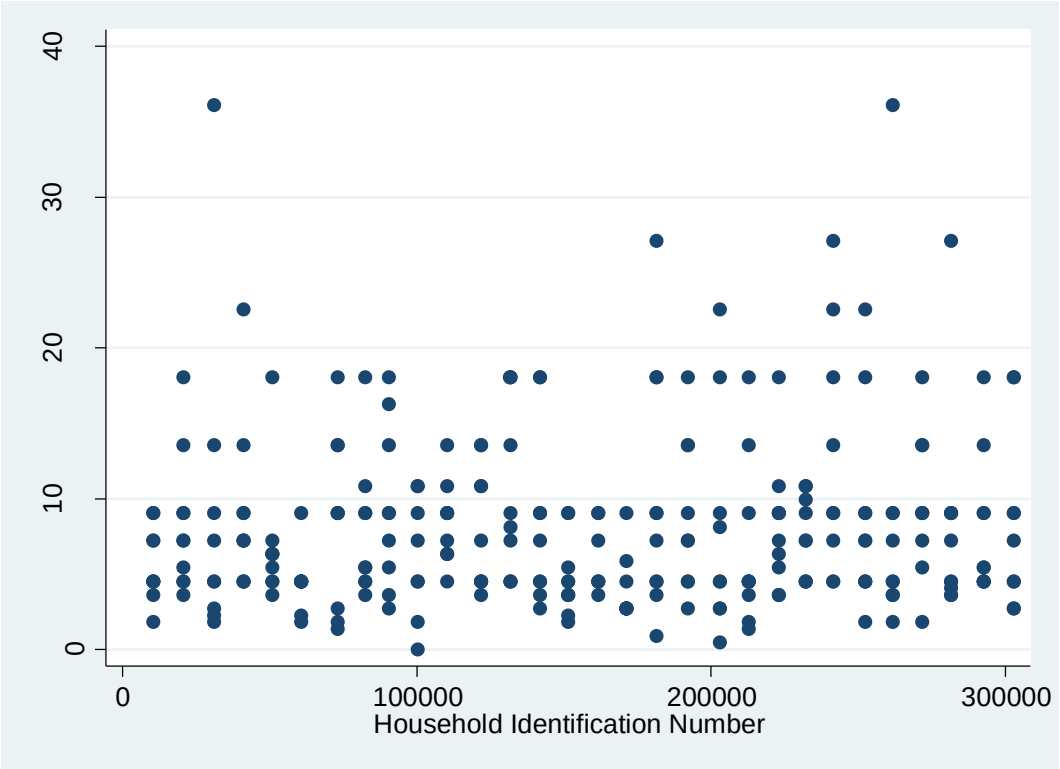
[10] Unless otherwise stated, all statistical findings are for the agricultural year 2012/2013 (defined as November 2012 to October 2013).

Malawians without *nsima* would consider themselves to be food insecure, even if other food sources were abundant. This cultural belief has wide-reaching effects on nutrition security and agricultural policy.

4.5.2 Willingness to Pay for ICS

The average WTP for the clay stove is 8.02 USD.[11,12] As shown in Figure 4.1, the data is heavily skewed towards zero. Only 25% of respondents are willing to pay more than 9.02 USD for the clay stove.

Figure 4.1: WTP for Clay Stove



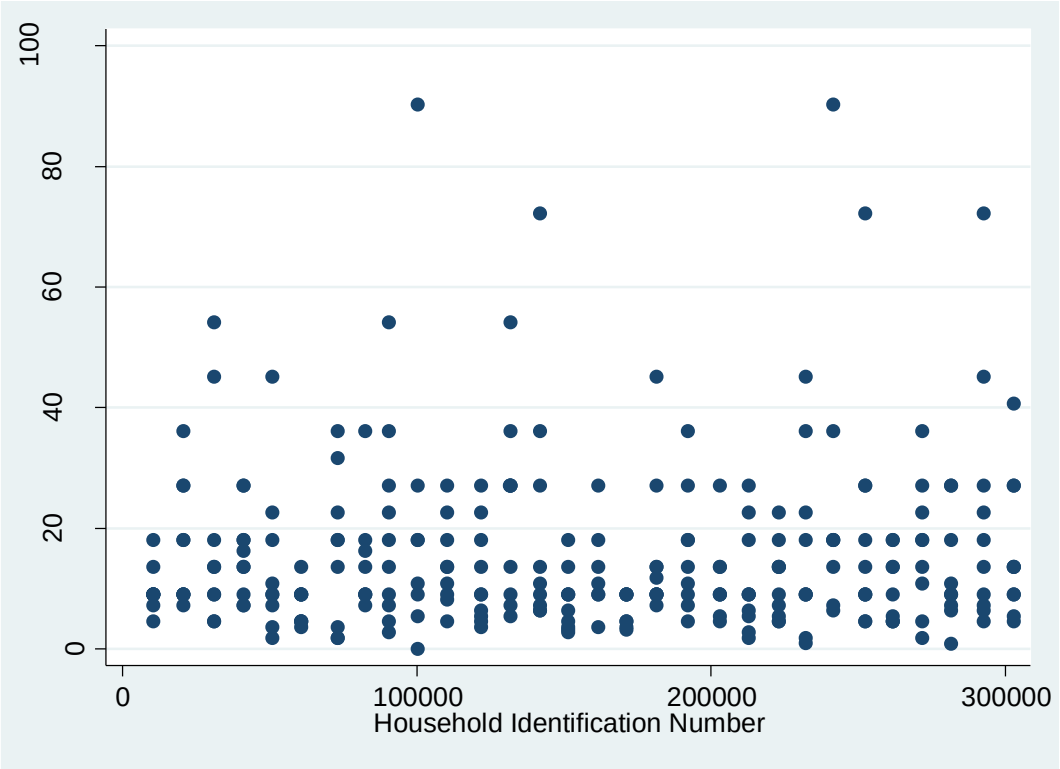
Source: Own survey, 2014, Stata output

The average WTP for the rocket stove is 15.34 USD. Again, the data is skewed towards zero, as shown in Figure 4.2. Only 25% of respondents are willing to pay more than 18.05 USD for the rocket stove.

[11] All USD 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.

[12] At the time of the survey, the clay stove sold at supermarkets and gas stations for 9.02 USD (adjusted for inflation and purchasing power parity).

Figure 4.2: WTP for Rocket Stove



Source: Own survey, 2014, Stata output

Because of the negative skew in the WTP for both stove types, ICS promoters should use the median, rather than the mean, when making pricing decisions to avoid overestimates. The median WTP is 7.22 USD and 9.03 USD, for the clay stove and the rocket stove, respectively.

Hypothetical bias appears to be a threat, especially in the rocket stove results, as some of the reported WTPs may be considered unreasonably high. Thirteen respondents are willing to pay the equivalent of more than 12 days of hard labor wages.[13] Otherwise, these high WTP results may be attributed to respondents being eager to adopt a new technology.

4.5.3 Socio-Economic Determinants of Willingness to Pay

Regressions were run on the both WTP models using estimates of robust standard errors. To achieve models that were as a whole statistically significant at the 10% level or better, the number of independent variables was reduced from 11 to three in the clay stove model and to five in the rocket stove model. Both of the resulting models passed the regression diagnostic test for

[13] 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).

multicollinearity, but only the clay stove model passed the diagnostic test for model specification, the Ramsey Regression Equation Specification Error Test (Ramsey RESET). The failure of the rocket stove model to pass the Ramsey RESET indicates that there are explanatory variables missing from the model. Both models, despite the use of robust standard error estimates, have vertically spread distribution of residuals indicating that there are respondents whose WTP is influenced by unknown factors. The distrust of, or disinterest in, new technology is suspected to be an important intangible variable.

The regression results of both models are shown in Tables 4.2 and 4.3. Both regressions yield low R-squared and adjusted R-squared values, indicating that the independent variables have limited predictive power and should be used only for explanatory purposes. There are small but reliable relationships between the independent and dependent variables.

Table 4.2:

Clay Stove Regression Results

Linear regression				Number of obs	=	273
				F(3, 269)	=	2.08
				Prob > F	=	0.1038
				R-squared	=	0.0246
				Root MSE	=	5.6283
				Adjusted R-squared	=	0.0138

WTP for Clay Stove	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Social Network Score	-.0715312	.0569251	-1.26	0.210	-.0721934
Household Dietary Diversity Score	.3645998	.1934134	1.89	0.060	.1370554
Amount Spent on Fuel (USD per month)	-.0499961	.0303674	-1.65	0.101	-.0813125
Constant	6.833105	1105005	6.18	0.000	.

Source: Own survey, 2014, Stata output

* Indicates statistical significance at the 10% level.

Table 4.3:

Rocket Stove Regression Results

Linear regression	Number of obs	=	271
	F(5, 265)	=	3.09
	Prob > F	=	0.0099
	R-squared	=	0.0934
	Root MSE	=	13.13
	Adjusted R-squared	=	0.0763

WTP for Rocket Stove	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Social Network Score	-.1147545	.1341294	-0.86	0.393	-.0481666
Household Net Income (USD per capita)	.0114854	.0054435	2.11	0.036	.1949898
Household Dietary Diversity Score	1.291833	.5682548	2.27	0.024	.2054453
Sickness Score	-1.450235	.7768815	-1.87	0.063	-.0957259
Amount Spent on Fuel (USD per month)	-.1158185	.0791707	-1.46	0.145	-.0778656
Constant	10.03332	2.696223	3.72	0.000	.

Source: Own survey, 2014, Stata output

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

The WTP for a clay stove model is statistically significant at the 10% level. The model shows household dietary diversity to be positively correlated with WTP, as hypothesized. Ceteris paribus, an increase in the WTP for a clay stove by 0.36 USD can be explained by a household's consumption of one additional food group. It is interesting that those households with more balanced diets exhibit a need for improved cooking technology to facilitate the preparation of multiple food groups, while those households with less balanced diets do not, or because of their circumstances are unable to. Wealthier households in the sample have higher dietary diversity scores, shown by a pairwise correlation coefficient of 0.188 that is statistically significantly different from zero at the 1% level of error probability.

Counterintuitively, the model shows a negative correlation between the amount spent on fuel per month with the WTP for a clay stove. Ceteris paribus, a decrease in the WTP for a clay stove by 0.05 USD can be explained by the increase in monthly fuel expenditure by 1 USD. This finding may be due to illegal acquisition of fuel sources. If a household is acquiring the fuel illegally, for example from forest reserves, their fuel expenditure would be low or zero. They would likely be interested in reducing their fuel consumption through the purchase of an ICS, to reduce the risks associated with illegal fuel acquisition.[14]

The WTP for a rocket stove model as a whole is statistically significant at the 1% level. As predicted there is a positive correlation between net household income per capita and WTP. Ceteris paribus, an increase in the WTP for a rocket stove by 0.10 USD can be explained by a 10 USD increase in annual net income per capita. A greater effect was expected; this shows the need for stove demonstrations and other marketing efforts.

Household dietary diversity is an even stronger explanatory variable in the WTP for a rocket stove model than in the clay stove model. This is likely because the fuel efficiency of a rocket stove is even greater than that of a clay stove, meaning that households could cook more types of food with even less fuel. Ceteris paribus, an increase in the WTP for a rocket stove by 1.29 USD can be explained by the consumption of one additional food group by a household.

[14] Illegal fuel acquisition in Malawi is punishable by fines and prison time. Women and girls are traditionally responsible for fuelwood collection; those who collect firewood illegally are particularly at risk of sexual abuse by forest reserve guards and thus HIV contraction (White, 2010).

It was hypothesized that households with higher (worse) sickness scores would recognize the health benefits of ICS and therefore report a higher WTP, however, the opposite was revealed in the regression results. Ceteris paribus, a decrease in the WTP for a rocket stove by 1.45 USD can be explained by one additional cooking-related ailment within the household. This finding may be due to illnesses affecting households' ability to generate income, and thus their willingness to purchase new technologies. Or, it is possible that the sickness score variable is flawed, causing the regression results to be erroneous. Several studies have explored the reliability of health self-assessment variables (Bound, 1989; Dunning et al., 2004; Martikainen et al., 2003); results are mixed but the subjectivity of health is unanimously accepted. The relationship between wealth and self-rated health scores are of particular interest in developing countries where the poorest may score themselves as healthy because of illiteracy and lack of disease awareness, while the better-off may score themselves as ill because of their improved ability to identify illness (King et al., 2004; Salomon et al., 2004; Sen, 1993; Sen, 2002). On the other hand, a study by Subramanian et al. (2009) finds the inverse to be true: that self-reported morbidity is more likely among the disadvantaged and least educated.

Of the seven independent variables that were not found to have explanatory power in either of the WTP models, credit access score and household size were most expected to be statistically significant. Credit access likely did not have an impact on WTP because respondents would not be willing to go into debt to purchase a stove. Larger households were hypothesized to be willing to pay more for ICS, because speed of food preparation and fuel savings would have the greatest relative returns for them. It is probable, however, since household size is largely accepted as a predictor of poverty (Lanjouw, 1995), that larger households have more thinly spread income and so are unable to invest in a new stove. Or, it is possible, that the larger households have more available labor to devote to collecting firewood, and therefore, the fuel efficiency of the ICS is not as attractive as it is to labor constrained households.

4.6 Discussion and Conclusions

This study finds four socioeconomic indicators that explain WTP for clay stoves and rocket stoves. Household dietary diversity is positively correlated with WTP for both the clay stove and the rocket stove. Fuel expenditures are negatively correlated with WTP for the clay stove. Annual

net income per capita is positively correlated with WTP for the rocket stove. Cooking-related ailments are negatively correlated with WTP for the rocket stove.

The household dietary diversity score in the WTP for a rocket stove model had the greatest impact on WTP. Households that consume more food groups, either because they are better-off and can afford to, or because they are knowledgeable about nutrition and make it a priority, are keen to reduce the fuel costs associated with their diverse diets by purchasing an efficient stove. ICS promoters would do well to target those households first as early adopters who can influence their neighbors' perceptions informally (Rogers & Scott, 1997). Households that do not consume varied foods, either because they cannot afford to, or they are unaware of the benefits of a balanced diet, would then witness the fuel saving attributes of the ICS and become later adopters. This could potentially occur without further intervention from ICS promoters, resulting in program savings.

The negative correlation between fuel expenditure and WTP for a clay stove, most likely due to respondents looking to decrease their risky, illegal firewood collecting activities, is yet another reason for intensive ICS promotion. Greater fuel efficiency not only decreases pressure on forest resources, but it also relieves the burden of illegal activity from those who have no other options. A lower demand for firewood would alleviate some of the government's cost of patrolling forest reserves and slow deforestation.

Two groups that would benefit most from ICS adoption, large households and households with cooking-related ailments, are willing to pay less. Larger households have a lower WTP for ICS because their resources are spread more thinly across members, but they would reap the greatest relative returns to fuel savings. Households with cooking-related ailments may have lower income generating abilities and are unable to afford the very stoves that would improve their health situation. These two groups should be targeted with lower pricing by ICS promoters.

Household net income per capita, health indicators, dietary diversity, and fuel expenditure are useful explanatory variables in the WTP for ICS, but, as shown by the model specification tests and R-squared values, there are predictive variables that could not be revealed by this study. These could be uncovered by using a larger sample size, performing cooking demonstrations before the survey, and assessing exhibited WTP, rather than stated WTP.

Comparing these results with those of other studies, the major similarity is in the positive effect of income (El Tayeb Muneer & Mukhtar Mohamed, 2003; Jan, 2012; Pine et al., 2011; Takama et al., 2012). The overall low WTP for ICS can be explained by the fact that the sampled households are all poor and as such face difficult challenges in meeting their basic needs. The purchase of a stove with rather abstract benefits cannot be expected to be high on their priority list (Mobarak et al., 2012). Other socioeconomic factors that were hypothesized in this study to have an effect but were insignificant, were found to be significant in other studies. This may be indicative of the difference between eliciting stated WTP and recording exhibited WTP or observing adoption. As hypothesized in this study, being relatively more educated increases the likelihood of ICS adoption in the literature (El Tayeb Muneer & Mukhtar Mohamed, 2003; Jan, 2012). This study anticipated that households suffering from cooking related ailments would be eager to purchase a stove and improve their health, and this is confirmed by Pine et al. (2011) who show that sufferers of eye irritation were twice as likely to be early adopters. An interesting and valuable study objective would be to determine to what extent observed adoption is a more reliable variable than stated WTP, as the latter is less costly and easier to collect in a household survey.

A weakness of this study is that respondents were shown the ICS models in a group meeting, but no cooking demonstration was done. Had the respondents experienced the fuel efficiency firsthand they may have reported higher WTP. In the literature, understanding of the advantages of ICS models and exposure to ICS promotional materials are found to be a strong positive factor in stove adoption (El Tayeb Muneer & Mukhtar Mohamed, 2003; Jan, 2012). ICS programs should heed this and be sure to give demonstrations in areas where stove sales are planned.

Because of the discrepancy between short-term and long-term impacts of ICS adoption, the focus of ICS programs should be sustained, proper stove use by adopters, not just dissemination (Pine et al., 2011; Ruiz-Mercado et al., 2011). Positive impact estimates are inflated when only short-term adoption data and laboratory fuel test results are used; more long-term impact evaluations are needed (Bensch & Peters, 2013; Hanna et al., 2012; Pine et al., 2011; Ruiz-Mercado et al., 2011). Further, the study of socioeconomic determinants of ICS adoption alone is inadequate for a self-sustaining, unsubsidized ICS market. Choice elicitation experiment studies on product-specific attributes, that is stove characteristics, should complement socioeconomic findings to

determine what is most desired by the target market. Knowing which type of ICS should be sold at what price to maximize sustained adoption by rural populations in developing countries may preserve the environment and improve human health until clean fuel can be made accessible to all.

4.7 References

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5. General Discussion and Conclusions

The studies in this thesis sought to provide microeconomic modelling results for the use of policy makers in the three overlapping food, energy and water (FEW) nexus sectors. Numerous factors contribute to Malawi's stifling poverty levels. This thesis concentrated on three: the limited use of efficient irrigation technologies by smallholder farmers, the exhaustion of the agricultural budget by a poorly executed maize subsidy, and the rapid destruction of forest resources as a result of inefficient fuel use. Respectively, three policy interventions were explored in this thesis: the expansion of irrigation management transfer programs, the replacement of Malawi's current fertilizer subsidy program with a conditional cash transfer program, and the promotion of sustained adoption of improved cookstoves. These three policy interventions are interrelated when viewed from the FEW nexus perspective.

This final section summarizes the results of the studies, discusses the limitations of the studies, gives suggestions for future research, and provides policy recommendations.

5.1 Summary of Results

Chapter 2 of this thesis was a study on the willingness of smallholder farmers to invest in community owned irrigation schemes. The hypothetical investments were contributions of both money and volunteer labor, for four different irrigation technologies. The study is well-suited to the FEW nexus perspective as the promotion of irrigation management transfer (IMT) programs has effects on all three nodes of the nexus. The expansion of irrigation may make a negative impact on water supply in the water sector, and the potential for hydropower in the energy sector (Rasul, 2014). However, irrigation expansion can be expected to improve yields and thus security in the food sector (Bazilian et al., 2011).

The uniqueness of this study is the main finding, that farmers are willing to contribute unpaid labor in addition to, or instead of, capital. IMT planners may use this information to develop individually tailored investment packages for IMT stakeholders. Additionally, household characteristics that were associated with a willingness to invest relatively more unpaid labor and money were a larger household labor endowment, a more educated main decision maker, a lesser amount of land under operation, a stronger social network, a higher perceived importance of

irrigation, and the location of the household at a higher elevation. These findings are important to future targeting and implementation of IMT programs. In producing models with only limited predictive value, 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 success of IMT, and thus the positive impacts on the nexus sectors, depends on clear communication of expectations among stakeholders.

Chapter 3 of this thesis was a study on the preferences of smallholder farmers for a conditional cash transfer (CCT) over a fertilizer subsidy coupon. The dominance of Malawi's Farm Input Subsidy Program (FISP) over the agricultural budget means that a less costly, more efficient alternative, like a CCT program, would have wide-reaching effects in all three of the FEW nexus sectors. The FISP's intense focus on maize cultivation crowds out opportunities for biofuel growth in the energy sector, and the contested success of the FISP has effects food stocks and security in the food sector (Dorward, Chirwa, Boughton, et al., 2008; Dorward, Chirwa, Kelly, et al., 2008). The conditionality of CCTs can be used to directly target certain sectors. In the case of this hypothetical CCT the cash would be provided on the condition of adoption of agroforestry techniques, providing benefits to the food sector through crop diversity, as well as indirect effects on the water and energy sectors. Because CCT recipients are free to spend the cash any way they choose, the CCT would impact all three sectors.

The FISP has been found in the literature to benefit the relatively better-off and politically connected households, rather than the economically and socially most vulnerable households (Chibwana, Fisher, Jumbe, Masters, & Shively, 2010; Chibwana, Fisher, & Shively, 2012; Dorward, Chirwa, Kelly, et al., 2008; Holden & Lunduka, 2012), and the results of this study support that. Although great care was taken to distinguish the hypothetical fertilizer coupon of the choice experiment from the current FISP coupons in circulation in Malawi, it is likely that respondents were biased by their experiences with the FISP. The regression models show that a preference for the CCT can in some cases be explained by a lower household net income, a higher elevation, and a female main agricultural decision maker. If a CCT is properly targeted and reaches the most vulnerable beneficiaries, the benefits to the nexus sectors can be fully realized.

Chapter 4 of this thesis was a study on the willingness of smallholder farmers to pay for two types of improved cookstove (ICS) and the socioeconomic traits that determine their willingness

to pay (WTP), to assist ICS program planners with targeting and pricing. The promotion of sustained ICS adoption is an excellent example of a FEW nexus intervention, given the strong effects on each of the nexus nodes. The fuel efficiency of ICS decreases the amount of biomass used for cooking, which slows deforestation and thus erosion, which has a positive effect on the energy and water sectors (García-Frapolli et al., 2010). The fuel efficiency means dietary diversity can improve with the inclusion of slow-cooking, protein-rich legumes (Nielsen et al., 2015). The high morbidity rates caused by reliance on biomass fuels for cooking will decline with sustained ICS adoption and proper use, resulting in human health improvements that will affect all three nodes of the nexus (Bensch & Peters, 2012; Hanna, Duflo, & Greenstone, 2012; Martin II, Glass, Balbus, & Collins, 2011). There will be further effects on all three sectors resulting from advancements in gender equality and climate change mitigation (Bensch & Peters, 2012; Hanna et al., 2012).

The study found four socioeconomic indicators to have explanatory power in models of WTP for the two types of ICS. Household dietary diversity is positively correlated with WTP for both the clay stove and the rocket stove. Fuel expenditures are negatively correlated with WTP for the clay stove. Annual net income per capita is positively correlated with WTP for the rocket stove. Cooking-related ailments are negatively correlated with WTP for the rocket stove. The WTP for an ICS of either type was generally low, as the respondents' income levels were low and they have difficulty meeting their basic needs. The purchase of a stove with rather abstract benefits cannot be expected to be high on their priority list, which is why ICS promotion must be well planned and effective for all nexus outcomes of widespread ICS adoption to be achieved (Mobarak, Dwivedi, Bailis, Hildemann, & Miller, 2012).

5.2 Study Limitations and Research Recommendations

Considering the nexus context, the main limitations of the studies contained in this thesis are that the analyses were performed at the microeconomic level. Macroeconomic modelling is needed to evaluate the synergies and trade-offs of nexus interventions, something that cannot be done with microeconomic modelling. For example, the findings in Chapter 2 indicate the extent to which smallholder farmers are interested in new irrigation schemes, but the microeconomic results cannot tell what effects irrigation expansion could have on the nexus. Irrigation expansion would almost certainly improve yields and food security for the smallholder farmers, but it cannot be

determined at the microeconomic level if the resulting increase in water use would have other consequences. Nor can it predict if those consequences would outweigh the benefits derived from higher yields. The microeconomic data could, however, be extrapolated to the national level and used in water models as estimates for irrigation expansion, and then used in an economy-wide model to determine effects on the food, water, and energy sectors. Microeconomic research can provide data and empirical evidence for use in macroeconomic frameworks, but without the wider perspective, household data can do little to evaluate impacts on all nexus sectors. It is therefore recommended that future studies be collaborative efforts between microeconomic and macroeconomic researchers, so that each may gain insight from the other, and provide more holistic study results to policy makers.

The regression models in Chapter 2 could be improved with a larger sample size. 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. Because the irrigation schemes were hypothetical, actual investments could not be observed, so the study was limited to the use of stated willingness to invest. Stated willingness to invest is not entirely reliable given the threat of hypothetical bias. However, the data shows reasonable and conservative willingness to invest levels. The investment levels reported in the study may also be inflated by the fact that the survey was conducted during the period immediately after harvest. Farmers had finished the majority of their hard labor for the season, had full grain stores, and had cash on hand from crop sales. Future research conducted during at different times throughout the year would account for this bias.

As in Chapter 2, the regression models in Chapter 3 would likely benefit from a larger sample size. The addition of observations could increase the predictive power of the models. Although great care was taken to highlight the hypothetical nature of both the CCT and the fertilizer coupon, it is likely that respondents were biased by their experience with the FISP. That created an imbalance in the experiment: comparing a hypothetical intervention with a known intervention. Future research may improve on this by actually offering a CCT for a period of time prior to the survey, so that respondents may gain firsthand experience and be better informed in their decision making.

The predictive power of the regression models in Chapter 4 could be improved by a larger sample size and the use of observed ICS adoption, rather than just stated WTP. Two important independent variables, education level and suffering from cooking related ailments, were hypothesized to be impact respondents' WTP, but were statistically insignificant in the regression models. Other studies that observed ICS adoption found those same variables to be strong predictors (El Tayeb Muneer & Mukhtar Mohamed, 2003; Jan, 2012; Pine et al., 2011). An interesting and valuable study objective would be to determine to what extent exactly observed adoption is a more reliable variable than stated WTP, as the latter is less costly and easier to collect in a household survey. Another weakness of the study is that respondents were not given the opportunity to experience the benefits of the ICS models firsthand, but rather based their stated WTPs on the presentation of the stoves in a group meeting. This likely lowered the reported WTP. In the literature, understanding of the advantages of ICS models and exposure to ICS promotional materials are found to be a strong positive factor in stove adoption (El Tayeb Muneer & Mukhtar Mohamed, 2003; Jan, 2012). Further, the study of socioeconomic determinants of ICS adoption alone is inadequate for a self-sustaining, unsubsidized ICS market. Choice elicitation experiment studies on product-specific attributes, that is stove characteristics, should complement socioeconomic findings to determine what is most desired by the target market.

5.3 Policy Recommendations

Given the findings of the study in Chapter 2, IMT planners are encouraged to develop individually tailored investment packages for IMT stakeholders. Realistic investment agreements make IMT programs run smoothly, and allowing smallholder farmers to invest labor when capital is scarce would likely be an effective way of ensuring that investment promises are honored. Farmers that viewed irrigation to be important to crop yields, and those with strong social networks were generally willing to invest more in irrigation schemes. Both of those traits imply a vested interest and dedication to the running of a communal scheme, so IMT program planners would likely have long-term success engaging with such farmers. Regardless of the explanatory variables, IMT managers must err on the conservative side when devising a project's financial plans as subsistence farmers cannot be expected to be reliable investors. Poor smallholder farmers often must take the short-term view of the future, deferring long-term goals to meet immediate needs.

Even the smallest investment in an irrigation scheme could be a hardship for a household. Further, their cash flows and labor availability are subject to the agricultural season.

The findings in Chapter 3 suggest that a CCT would be a good alternative to the FISP, especially from the FEW nexus perspective. The FISP has been found to benefit better-off, politically connected households more so than its intended targets (Chibwana et al., 2010; Chirwa, Matita, & Dorward, 2011; Dorward & Chirwa, 2013). The study in Chapter 3 confirmed this to a degree by showing that vulnerable households, including those with female main decision makers, those with the lowest incomes, and those that are geographically remote, were most interested in a CCT. Further, the conditionality of a CCT could be used to ameliorate deforestation, one of Malawi's biggest challenges. It is recommended that policy makers consider replacing all of part of the FISP with a CCT. A well-targeted, transparent CCT program could place Malawi among other developing countries that have reaped the benefits of progressing from price interventions to income interventions.

Several recommendations to policy makers can be made based on the findings from the study in Chapter 4. First, in order to maximize sustained ICS adoption rates, the stoves should be promoted heavily. As found in the literature, cooking demonstrations and promotional materials are crucial to ICS adoption rates (El Tayeb Muneer & Mukhtar Mohamed, 2003; Jan, 2012). Given the economic situation of subsistence farmers, the purchase of a stove with rather abstract benefits cannot be expected to be high on their priority list (Mobarak et al., 2012). Second, ICS adoption could become self-driven if ICS promoters identify and target early adopters and social leaders who can informally influence the perceptions of their community members (Rogers & Scott, 1997). Further, policy makers should not be misled by over-stated impact estimates based only on short-term adoption data and laboratory fuel tests, instead planning should be done with the aid of long-run impact evaluations (Bensch & Peters, 2013; Hanna et al., 2012; Pine et al., 2011; Ruiz-Mercado, Masera, Zamora, & Smith, 2011). The goal of ICS promotion should be sustained, proper stove use, not just dissemination (Pine et al., 2011; Ruiz-Mercado et al., 2011).

The evaluation of economic interventions from a nexus perspective is becoming increasingly common in the literature. It is time now for the nexus perspective to cross-over into the policy making realm and become the new framework standard through which development

decisions are made. With the paradigm shift will hopefully come alleviation of the pressure that the Earth's resources are currently under.

5.5 References

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7. APPENDICES

Appendices A, B, and C pertain to Chapters 2, 3, and 4, respectively. Appendix D provides maps of the survey area, and Appendix E presents sections of the household questionnaire that are relevant to this thesis.

Appendix A

Figure A1: Treadle pump

Photo by: SkiPumps

Figure A2: Motorized pump

Photo by: IWMI.org

Figure A3: Canal irrigation

Photo by: IFAD

Figure A4: Bound basin flooding

Photo by: ipsnews.net

Table A1: Regression results for willingness to invest capital in construction of treadle pump

Linear regression

Number of obs	=	294
F(12, 281)	=	1.39
Prob > F	=	0.1675
R-squared	=	0.0423
Root MSE	=	5422.8
Adjusted R-squared	=	.0013

Capital for Construction of Treadle Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	56.34989	135.5123	0.42	0.678	.0241391
Percent male labor	2216.94	1694.535	1.31	0.192	.1105948
Social network score	57.31926	47.09796	1.22	0.225	.0603789
Net per capita income	.0070706	.0106468	0.66	0.507	.0328832
Per capita number of parcels	1471.479	653.0987	2.25	0.025	.1566062
Per capita hectares of land	-1113.409	582.6371	-1.91	0.057	-.1154993
Average distance to market	.6758012	4.524594	0.15	0.881	.0078159
Elevation	.4779094	1.189053	0.40	0.688	.0271189
Gender of decision maker	-8.400278	556.0754	-0.02	0.988	-.000731
Education level of decision maker	-206.5559	331.8154	-0.62	0.534	-.0354661
Risk self-assessment score	109.038	78.68072	1.39	0.167	.073846
Importance of irrigation	63.31441	178.6208	0.35	0.723	.0166603
Constant	-441.2838	1585.142	-0.28	0.781	.

Source: Own survey, 2014, Stata output

Table A2: Regression results for willingness to invest unpaid labor in maintenance of treadle pump

Linear regression

Number of obs	=	292
F(12, 279)	=	1.95
Prob > F	=	0.0291
R-squared	=	0.0821
Root MSE	=	197.67
Adjusted R-squared	=	.0426

Unpaid Labor for Maintenance of Treadle Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	4.591588	5.215409	0.88	0.379	.052962
Percent male labor	129.9744	53.08557	2.45	0.015	.1730477
Social network score	-.5855461	2.022927	-0.29	0.772	-.016558
Net per capita income	.000653	.0006412	1.02	0.309	.0816777
Per capita number of parcels	18.484	23.88894	0.77	0.440	.0529752
Per capita hectares of land	-53.11008	21.7234	-2.44	0.015	-.1483344
Average distance to market	-.1530552	.1735459	-0.88	0.379	-.0476201
Elevation	.0742865	.0294754	2.52	0.012	.1125664
Gender of decision maker	48.48785	35.20289	1.38	0.169	.1135317
Education level of decision maker	25.36929	16.41785	1.55	0.123	.1161052
Risk self-assessment score	1.699674	3.414291	0.50	0.619	.0309772
Importance of irrigation	9.527933	9.009247	1.06	0.291	.0675323
Constant	-66.01142	57.5998	-1.15	0.253	.

Source: Own survey, 2014, Stata output

Table A3: Regression results for willingness to invest capital in maintenance of treadle pump

Linear regression

Number of obs	=	294
F(12, 281)	=	1.92
Prob > F	=	0.0319
R-squared	=	0.0733
Root MSE	=	5110.6
Adjusted R-squared	=	.0338

Capital for Maintenance of Treadle Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	20.29525	127.8225	0.16	0.874	.0090743
Percent male labor	2118.267	1193.581	1.77	0.077	.1102946
Social network score	126.5376	59.36793	2.13	0.034	.1391224
Net per capita income	.0147006	.0195462	0.75	0.453	.0713585
Per capita number of parcels	847.7984	592.5908	1.43	0.154	.094176
Per capita hectares of land	-515.6546	498.0384	-1.04	0.301	-.0558311
Average distance to market	3.091876	4.605171	0.67	0.503	.0373226
Elevation	-1.834005	1.534731	-1.20	0.233	-.1086226
Gender of decision maker	402.4691	765.6019	0.53	0.600	.0365542
Education level of decision maker	115.7188	309.2356	0.37	0.709	.0207382
Risk self-assessment score	-55.45927	71.24524	-0.78	0.437	-.0392027
Importance of irrigation	408.917	215.1247	1.90	0.058	.112307
Constant	1126.736	1871.988	0.60	0.548	.

Source: Own survey, 2014, Stata output

Table A4: Regression results for willingness to invest unpaid labor in management of treadle pump

Linear regression

Number of obs	=	294	
F(12, 281)	=	1.36	
Prob > F	=	0.1873	
R-squared	=	0.0815	
Root MSE	=	168.02	
Adjusted R-squared	=	.0423	

Unpaid Labor for Management of Treadle Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	14.59723	9.028616	1.62	0.107	.1976409
Percent male labor	7.96639	43.61834	0.18	0.855	.0125609
Social network score	-.2099661	1.657817	-0.13	0.899	-.0069906
Net per capita income	.0002484	.0003837	0.65	0.518	.0365085
Per capita number of parcels	65.00531	41.55091	1.56	0.119	.2186668
Per capita hectares of land	-83.16281	41.79475	-1.99	0.048	-.272667
Average distance to market	.1268933	.1918229	0.66	0.509	.0463848
Elevation	.0483269	.0305947	1.58	0.115	.0866752
Gender of decision maker	-14.28477	23.3243	-0.61	0.541	-.0392884
Education level of decision maker	-4.58583	11.20296	-0.41	0.683	-.024887
Risk self-assessment score	1.124894	2.945794	0.38	0.703	.0240791
Importance of irrigation	2.657761	6.931481	0.38	0.702	.0221042
Constant	-3.392389	48.65759	-0.07	0.944	.

Source: Own survey, 2014, Stata output

Table A5: Regression results for willingness to invest capital in management of treadle pump

Linear regression

Number of obs	=	294
F(12, 281)	=	1.69
Prob > F	=	0.0675
R-squared	=	0.1083
Root MSE	=	4921.2
Adjusted R-squared	=	.0702

Capital for Management of Treadle Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	54.39376	115.8782	0.47	0.639	.0247757
Percent male labor	852.9671	845.1179	1.01	0.314	.0452442
Social network score	39.5458	58.15286	0.68	0.497	.044293
Net per capita income	.051265	.0441513	1.16	0.247	.2535063
Per capita number of parcels	650.7811	455.5343	1.43	0.154	.0736444
Per capita hectares of land	-948.6892	408.7901	-2.32	0.021	-.1046401
Average distance to market	5.448552	4.394231	1.24	0.216	.0670022
Elevation	-1.500303	1.525248	-0.98	0.326	-.0905223
Gender of decision maker	-457.6377	630.0411	-0.73	0.468	-.0423432
Education level of decision maker	-257.8109	347.9267	-0.74	0.459	-.0470681
Risk self-assessment score	-68.57416	62.71635	-1.09	0.275	-.049381
Importance of irrigation	236.7725	200.9504	1.18	0.240	.0662461
Constant	2251.766	1877.546	1.20	0.231	.

Source: Own survey, 2014, Stata output

Table A6: Regression results for willingness to invest capital in construction of motor pump

Linear regression

Number of obs	=	296
F(12, 283)	=	1.65
Prob > F	=	0.0768
R-squared	=	0.0455
Root MSE	=	7664.1
Adjusted R-squared	=	.0051

Capital for Construction of Motorized Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	72.06404	198.3338	0.36	0.717	.0217606
Percent male labor	1243.741	1314.486	0.95	0.345	.0440139
Social network score	70.34656	69.88028	1.01	0.315	.052543
Net per capita income	.0202475	.019019	1.06	0.288	.0644708
Per capita number of parcels	1933.359	835.5662	2.31	0.021	.1444672
Per capita hectares of land	-1406.935	589.4891	-2.39	0.018	-.1027555
Average distance to market	2.696614	6.742533	0.40	0.690	.021964
Elevation	-.2859998	1.530249	-0.19	0.852	-.011364
Gender of decision maker	-1278.143	820.7511	-1.56	0.121	-.0784164
Education level of decision maker	-311.496	581.3464	-0.54	0.593	-.0377637
Risk self-assessment score	193.3152	114.1541	1.69	0.091	.0925521
Importance of irrigation	25.55178	277.6523	0.09	0.927	.0047374
Constant	1251.737	1974.94	0.63	0.527	.

Source: Own survey, 2014, Stata output

Table A7: Regression results for willingness to invest unpaid labor in maintenance of motor pump

Linear regression

Number of obs	=	294
F(12, 281)	=	1.63
Prob > F	=	0.0841
R-squared	=	0.0793
Root MSE	=	221.3
Adjusted R-squared	=	.0400

Unpaid Labor for Maintenance of Motorized Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	14.65616	8.470287	1.73	0.085	.1509102
Percent male labor	62.2489	61.97409	1.00	0.316	.0750067
Social network score	1.344733	2.726317	0.49	0.622	.0340756
Net per capita income	.0007783	.0009354	0.83	0.406	.0845591
Per capita number of parcels	-24.00721	28.20837	-0.85	0.395	-.0610656
Per capita hectares of land	4.103243	26.71276	0.15	0.878	.0102103
Average distance to market	-.2697977	.149869	-1.80	0.073	-.0748795
Elevation	.1068116	.0356389	3.00	0.003	.1437741
Gender of decision maker	45.57091	27.86194	1.64	0.103	.0950254
Education level of decision maker	12.15452	14.0882	0.86	0.389	.0497431
Risk self-assessment score	-5.149421	3.75715	-1.37	0.172	-.0840744
Importance of irrigation	-7.194971	8.689444	-0.83	0.408	-.0453613
Constant	-2.659764	60.23705	-0.04	0.965	.

Source: Own survey, 2014, Stata output

Table A8: Regression results for willingness to invest capital in maintenance of motor pump

Linear regression

Number of obs	=	296
F(12, 283)	=	1.43
Prob > F	=	0.1496
R-squared	=	0.0770
Root MSE	=	6230.6
Adjusted R-squared	=	.0378

Capital for Maintenance of Motorized Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	-56.4454	141.3927	-0.40	0.690	-.0206175
Percent male labor	1554.908	1583.072	0.98	0.327	.0665608
Social network score	120.8672	66.64854	1.81	0.071	.1092031
Net per capita income	.0326301	.0245495	1.33	0.185	.1256798
Per capita number of parcels	1659.853	1130.402	1.47	0.143	.150031
Per capita hectares of land	-1296.407	791.2756	-1.64	0.102	-.114532
Average distance to market	10.41687	6.343375	1.64	0.102	.1026322
Elevation	-1.340819	1.562638	-0.86	0.392	-.0644451
Gender of decision maker	-456.2589	751.5758	-0.61	0.544	-.0338605
Education level of decision maker	277.0109	443.6388	0.62	0.533	.0406231
Risk self-assessment score	33.0848	84.66682	0.39	0.696	.0191604
Importance of irrigation	400.7809	241.9708	1.66	0.099	.0898835
Constant	-60.25604	2023.477	-0.03	0.976	.

Source: Own survey, 2014, Stata output

Table A9: Regression results for willingness to invest unpaid labor in management of motor pump

Linear regression

Number of obs	=	296
F(12, 283)	=	1.94
Prob > F	=	0.0300
R-squared	=	0.0381
Root MSE	=	226.28
Adjusted R-squared	=	-.0027

Unpaid Labor for Management of Motorized Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	3.719297	5.094277	0.73	0.466	.0381871
Percent male labor	14.15709	43.68381	0.32	0.746	.0170348
Social network score	2.675626	2.427304	1.10	0.271	.0679517
Net per capita income	.00082	.0006965	1.18	0.240	.0887815
Per capita number of parcels	7.363125	26.11739	0.28	0.778	.0187078
Per capita hectares of land	-13.3448	21.09684	-0.63	0.528	-.0331395
Average distance to market	-.20405	.1481504	-1.38	0.170	-.0565108
Elevation	.0919735	.0360984	2.55	0.011	.1242597
Gender of decision maker	20.56571	27.37984	0.75	0.453	.0429016
Education level of decision maker	-10.51361	14.67056	-0.72	0.474	-.0433387
Risk self-assessment score	-1.321935	3.689401	-0.36	0.720	-.0215196
Importance of irrigation	-3.408899	10.56418	-0.32	0.747	-.02149
Constant	-1.134133	64.79923	-0.02	0.986	.

Source: Own survey, 2014, Stata output

Table A10: Regression results for willingness to invest capital in management of motor pump

Linear regression

Number of obs	=	296
F(12, 283)	=	1.63
Prob > F	=	0.0819
R-squared	=	0.0710
Root MSE	=	4694.6
Adjusted R-squared	=	.0316

Capital for Management of Motorized Pump	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	29.68803	119.5209	0.25	0.804	.0144384
Percent male labor	206.5779	797.7878	0.26	0.796	.0117741
Social network score	80.35402	49.91244	1.61	0.109	.0966641
Net per capita income	.0214118	.0193822	1.10	0.270	.1098075
Per capita number of parcels	230.2693	464.2723	0.50	0.620	.0277127
Per capita hectares of land	-665.4509	439.8355	-1.51	0.131	-.0782766
Average distance to market	10.55237	5.172306	2.04	0.042	.1384289
Elevation	-1.62252	1.442142	-1.13	0.262	-.1038342
Gender of decision maker	-1055.881	611.0073	-1.73	0.085	-.1043344
Education level of decision maker	-186.5267	283.48	-0.66	0.511	-.0364207
Risk self-assessment score	-5.805982	65.54577	-0.09	0.929	-.0044769
Importance of irrigation	250.2294	205.1111	1.22	0.223	.0747209
Constant	2216.688	1635.798	1.36	0.176	.

Source: Own survey, 2014, Stata output

Table A11: Regression results for willingness to invest unpaid labor in construction of canal

Linear regression

Number of obs	=	210
F(12, 197)	=	2.83
Prob > F	=	0.0013
R-squared	=	0.0920
Root MSE	=	8.9019
Adjusted R-squared	=	.0367

Unpaid Labor for Construction of Canal	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	-.1663843	.248203	-0.67	0.503	-.0420731
Percent male labor	-1.045196	2.624132	-0.40	0.691	-.0310462
Social network score	-.0002594	.1045912	-0.00	0.998	-.000162
Net per capita income	-.0000291	.000018	-1.62	0.107	-.0773856
Per capita number of parcels	.5538338	1.630432	0.34	0.734	.0338661
Per capita hectares of land	-2.572869	1.281347	-2.01	0.046	-.1515848
Average distance to market	-.0035402	.00805	-0.44	0.661	-.025649
Elevation	.0010813	.0020097	0.54	0.591	.0393889
Gender of decision maker	-3.141405	1.447108	-2.17	0.031	-.1624614
Education level of decision maker	1.372544	.6077691	2.26	0.025	.142801
Risk self-assessment score	-.1670616	.1738284	-0.96	0.338	-.0663802
Importance of irrigation	.8483898	.4815595	1.76	0.080	.1303175
Constant	7.971355	3.207257	2.49	0.014	.

Source: Own survey, 2014, Stata output

Table A12: Regression results for willingness to invest capital in construction of canal

Linear regression

Number of obs	=	210
F(12, 197)	=	1.77
Prob > F	=	0.0555
R-squared	=	0.1084
Root MSE	=	3340.4
Adjusted R-squared	=	.0541

Capital for Construction of Canal	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	14.1865	104.6587	0.14	0.892	.0094731
Percent male labor	1448.814	834.5698	1.74	0.084	.1136453
Social network score	40.20776	43.59094	0.92	0.357	.0663262
Net per capita income	.0290422	.0251991	1.15	0.251	.203894
Per capita number of parcels	452.7193	537.9424	0.84	0.401	.0731041
Per capita hectares of land	-153.6563	352.2457	-0.44	0.663	-.0239065
Average distance to market	.2329872	3.261911	0.07	0.943	.0044577
Elevation	-.0115748	.6458372	-0.02	0.986	-.0011135
Gender of decision maker	-587.1035	352.0299	-1.67	0.097	-.0801804
Education level of decision maker	160.3155	240.7311	0.67	0.506	.0440461
Risk self-assessment score	1.710131	58.67083	0.03	0.977	.0017944
Importance of irrigation	2.069051	142.291	0.01	0.988	.0008393
Constant	374.232	946.3583	0.40	0.693	.

Source: Own survey, 2014, Stata output

Table A13: Regression results for willingness to invest unpaid labor in maintenance of canal

Linear regression

Number of obs	=	210
F(12, 197)	=	2.31
Prob > F	=	0.0087
R-squared	=	0.1598
Root MSE	=	225.88
Adjusted R-squared	=	.1086

Unpaid Labor for Maintenance of Canal	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	-3.413569	5.420023	-0.63	0.530	-.0327228
Percent male labor	134.7502	77.75156	1.73	0.085	.1517368
Social network score	1.843416	3.528224	0.52	0.602	.0436537
Net per capita income	.0002072	.0005894	0.35	0.726	.0208799
Per capita number of parcels	11.75526	28.83565	0.41	0.684	.0272501
Per capita hectares of land	-40.63048	23.02197	-1.76	0.079	-.0907487
Average distance to market	-.1267637	.2049075	-0.62	0.537	-.0348172
Elevation	.0371508	.0684055	0.54	0.588	.0513057
Gender of decision maker	62.44826	35.29032	1.77	0.078	.1224326
Education level of decision maker	85.91831	27.01439	3.18	0.002	.3388762
Risk self-assessment score	-1.360154	4.695945	-0.29	0.772	-.020488
Importance of irrigation	8.160114	10.36099	0.79	0.432	.0475175
Constant	-57.16681	99.75083	-0.57	0.567	.

Source: Own survey, 2014, Stata output

Table A14: Regression results for willingness to invest capital in maintenance of canal

Linear regression

Number of obs	=	210
F(12, 197)	=	2.31
Prob > F	=	0.0088
R-squared	=	0.1905
Root MSE	=	4232.8
Adjusted R-squared	=	.1412

Capital for Maintenance of Canal	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	-156.4264	116.908	-1.34	0.182	-.0785455
Percent male labor	3145.577	1512.549	2.08	0.039	.1855371
Social network score	133.3535	59.78674	2.23	0.027	.1654136
Net per capita income	.0312723	.0237356	1.32	0.189	.1650921
Per capita number of parcels	1044.609	1037.345	1.01	0.315	.1268406
Per capita hectares of land	-234.3916	719.3383	-0.33	0.745	-.027422
Average distance to market	2.524929	3.665524	0.69	0.492	.036326
Elevation	1.031895	.8426715	1.22	0.222	.0746453
Gender of decision maker	674.5637	666.0704	1.01	0.312	.0692737
Education level of decision maker	1001.969	413.1862	2.42	0.016	.2070039
Risk self-assessment score	-72.47086	75.92854	-0.95	0.341	-.0571801
Importance of irrigation	393.6027	195.9753	2.01	0.046	.1200562
Constant	-3846.187	1737.245	-2.21	0.028	.

Source: Own survey, 2014, Stata output

Table A15: Regression results for willingness to invest unpaid labor in management of canal

Linear regression

Number of obs	=	210
F(12, 197)	=	2.12
Prob > F	=	0.0171
R-squared	=	0.0944
Root MSE	=	172.3
Adjusted R-squared	=	.0392

Unpaid Labor for Management of Canal	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	4.975154	6.374136	0.78	0.436	.0649111
Percent male labor	19.99588	52.27916	0.38	0.703	.0306459
Social network score	5.474921	2.695045	2.03	0.044	.17646
Net per capita income	-8.29e-06	.0003898	-0.02	0.983	-.0011375
Per capita number of parcels	15.3011	23.55754	0.65	0.517	.0482757
Per capita hectares of land	-37.62951	19.22488	-1.96	0.052	-.1143898
Average distance to market	-.3116577	.1412701	-2.21	0.029	-.1165058
Elevation	.0608471	.0371402	1.64	0.103	.114369
Gender of decision maker	16.46496	23.52597	0.70	0.485	.0439347
Education level of decision maker	34.81138	14.92026	2.33	0.021	.1868732
Risk self-assessment score	-2.087272	3.455223	-0.60	0.546	-.0427919
Importance of irrigation	-.295826	9.614887	-0.03	0.975	-.0023446
Constant	-15.0841	69.32259	-0.22	0.828	.

Source: Own survey, 2014, Stata output

Table A16: Regression results for willingness to invest capital in management of canal

Linear regression

Number of obs	=	210
F(12, 197)	=	2.30
Prob > F	=	0.0092
R-squared	=	0.1776
Root MSE	=	2795.1
Adjusted R-squared	=	.1275

Capital for Management of Canal	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	-168.3248	92.69032	-1.82	0.071	-.1290066
Percent male labor	1392.076	814.779	1.71	0.089	.1253275
Social network score	152.0105	42.20354	3.60	0.000	.2878016
Net per capita income	.0106876	.0089055	1.20	0.232	.086119
Per capita number of parcels	-9.395553	332.6411	-0.03	0.977	-.0017413
Per capita hectares of land	220.3746	372.6664	0.59	0.555	.0393524
Average distance to market	3.746218	2.964625	1.26	0.208	.0822649
Elevation	.3154716	.5159968	0.61	0.542	.0348321
Gender of decision maker	-176.2002	406.7324	-0.43	0.665	-.0276188
Education level of decision maker	537.5102	204.8925	2.62	0.009	.1694977
Risk self-assessment score	-33.52706	59.28152	-0.57	0.572	-.0403766
Importance of irrigation	237.1858	145.1692	1.63	0.104	.1104252
Constant	-1644.489	1054.811	-1.56	0.121	.

Source: Own survey, 2014, Stata output

Table A17: Regression results for willingness to invest unpaid labor in construction of bound basin

Linear regression

Number of obs	=	189
F(12, 176)	=	1.50
Prob > F	=	0.1291
R-squared	=	0.0672
Root MSE	=	7.0861
Adjusted R-squared	=	.0036

Unpaid Labor for Construction of Bound Basin	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	-.0152438	.2431237	-0.06	0.950	-.0047277
Percent male labor	-1.477669	1.835042	-0.81	0.422	-.0556831
Social network score	.012757	.0915086	0.14	0.889	.0104878
Net per capita income	-.0000157	.0000159	-0.99	0.325	-.0569559
Per capita number of parcels	1.338432	1.700374	0.79	0.432	.1011638
Per capita hectares of land	-1.684563	1.227463	-1.37	0.172	-.1272377
Average distance to market	-.0031418	.0065164	-0.48	0.630	-.0294068
Elevation	-.0013376	.0017494	-0.76	0.446	-.061404
Gender of decision maker	.0458331	1.115398	0.04	0.967	.002956
Education level of decision maker	.6714647	.5682373	1.18	0.239	.0902932
Risk self-assessment score	-.1089719	.1522731	-0.72	0.475	-.0545717
Importance of irrigation	.9378896	.4000972	2.34	0.020	.1793134
Constant	4.950282	2.747947	1.80	0.073	.

Source: Own survey, 2014, Stata output

Table A18: Regression results for willingness to invest capital in construction of bound basin

Linear regression

Number of obs	=	189
F(12, 176)	=	0.66
Prob > F	=	0.7922
R-squared	=	0.0412
Root MSE	=	2900.8
Adjusted R-squared	=	-.0242

Capital for Construction of Bound Basin	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	100.8337	133.2947	0.76	0.450	.0774464
Percent male labor	598.5957	643.0078	0.93	0.353	.0558627
Social network score	-.0987615	44.27096	-0.00	0.998	-.0002011
Net per capita income	.0032996	.0111605	0.30	0.768	.0297126
Per capita number of parcels	88.77772	401.4543	0.22	0.825	.0166178
Per capita hectares of land	-91.28287	301.1713	-0.30	0.762	-.017075
Average distance to market	2.66456	2.99322	0.89	0.375	.0617635
Elevation	-.7639462	.8429395	-0.91	0.366	-.0868501
Gender of decision maker	-404.8802	310.3875	-1.30	0.194	-.0646688
Education level of decision maker	146.656	193.5516	0.76	0.450	.0488398
Risk self-assessment score	30.73526	60.03093	0.51	0.609	.0381182
Importance of irrigation	-23.97641	145.9377	-0.16	0.870	-.0113524
Constant	1467.978	1290.904	1.14	0.257	.

Source: Own survey, 2014, Stata output

Table A19: Regression results for willingness to invest unpaid labor in maintenance of bound basin

Linear regression

Number of obs	=	189
F(12, 176)	=	0.77
Prob > F	=	0.6828
R-squared	=	0.0727
Root MSE	=	266.07
Adjusted R-squared	=	.0094

Unpaid Labor for Maintenance of Bound Basin	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	-.4446352	6.950686	-0.06	0.949	-.0036617
Percent male labor	58.03683	46.30807	1.25	0.212	.0580736
Social network score	-3.766554	3.055993	-1.23	0.219	-.0822257
Net per capita income	.0004133	.000732	0.56	0.573	.0399029
Per capita number of parcels	44.07038	44.71246	0.99	0.326	.0884513
Per capita hectares of land	-81.64153	43.12433	-1.89	0.060	-.1637451
Average distance to market	-.1590125	.3009259	-0.53	0.598	-.0395207
Elevation	-.0433432	.082632	-0.52	0.601	-.0528342
Gender of decision maker	-13.97676	34.36036	-0.41	0.685	-.0239366
Education level of decision maker	38.19766	24.14566	1.58	0.115	.1363947
Risk self-assessment score	-4.713115	5.875835	-0.80	0.424	-.0626744
Importance of irrigation	7.558906	13.93863	0.54	0.588	.038375
Constant	156.7251	112.9751	1.39	0.167	.

Source: Own survey, 2014, Stata output

Table A20: Regression results for willingness to invest capital in maintenance of bound basin

Linear regression

Number of obs	=	189
F(12, 176)	=	0.79
Prob > F	=	0.6557
R-squared	=	0.0617
Root MSE	=	3880.8
Adjusted R-squared	=	-.0022

Capital for Maintenance of Bound Basin	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	115.6573	182.5366	0.63	0.527	.0656866
Percent male labor	818.2537	1439.358	0.57	0.570	.0564656
Social network score	40.80491	49.18381	0.83	0.408	.0614323
Net per capita income	.0127722	.0175052	0.73	0.467	.0850464
Per capita number of parcels	815.9171	970.8929	0.84	0.402	.112934
Per capita hectares of land	-283.2288	643.7044	-0.44	0.660	-.0391756
Average distance to market	3.958126	3.036443	1.30	0.194	.0678429
Elevation	-.9306602	1.12228	-0.83	0.408	-.078236
Gender of decision maker	288.9749	622.9953	0.46	0.643	.03413
Education level of decision maker	344.6073	333.3283	1.03	0.303	.0848606
Risk self-assessment score	-93.4669	83.01127	-1.13	0.262	-.0857158
Importance of irrigation	17.34108	162.2843	0.11	0.915	.0060714
Constant	935.5619	2152.068	0.43	0.664	.

Source: Own survey, 2014, Stata output

Table A21: Regression results for willingness to invest unpaid labor in management of bound basin

Linear regression

Number of obs	=	189
F(12, 176)	=	0.39
Prob > F	=	0.9655
R-squared	=	0.0303
Root MSE	=	199.08
Adjusted R-squared	=	-.0358

Unpaid Labor for Management of Bound Basin	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	4.594046	5.575786	0.82	0.411	.0517064
Percent male labor	21.20129	33.59356	0.63	0.529	.0289937
Social network score	-1.83656	2.624161	-0.70	0.485	-.0547942
Net per capita income	-.0000641	.0004007	-0.16	0.873	-.0084612
Per capita number of parcels	40.01006	37.17111	1.08	0.283	.1097471
Per capita hectares of land	-48.83125	28.65924	-1.70	0.090	-.1338509
Average distance to market	-.2783776	.2643351	-1.05	0.294	-.0945571
Elevation	.0003778	.0458656	0.01	0.993	.0006294
Gender of decision maker	-5.6046	27.19813	-0.21	0.837	-.013118
Education level of decision maker	9.177859	15.54042	0.59	0.556	.0447887
Risk self-assessment score	-.7756902	4.097247	-0.19	0.850	-.0140973
Importance of irrigation	3.134249	11.25019	0.28	0.781	.0217465
Constant	86.70935	80.13626	1.08	0.281	.

Source: Own survey, 2014, Stata output

Table A22: Regression results for willingness to invest capital in management of bound basin

Linear regression

Number of obs	=	189
F(12, 176)	=	1.20
Prob > F	=	0.2859
R-squared	=	0.0520
Root MSE	=	1995.8
Adjusted R-squared	=	-.0126

Capital for Management of Bound Basin	*Coefficient*	*Robust Std. Err.*	*t*	*P>t*	*Beta*
Credit access score	45.8969	77.28518	0.59	0.553	.0509474
Percent male labor	341.4745	431.018	0.79	0.429	.0460563
Social network score	44.68074	35.6816	1.25	0.212	.1314738
Net per capita income	.0047322	.0056297	0.84	0.402	.0615871
Per capita number of parcels	209.7132	284.5581	0.74	0.462	.0567334
Per capita hectares of land	-264.9078	213.1769	-1.24	0.216	-.0716156
Average distance to market	2.843845	2.373149	1.20	0.232	.0952698
Elevation	-.1009511	.4782684	-0.21	0.833	-.0165868
Gender of decision maker	-155.9567	345.851	-0.45	0.653	-.0360011
Education level of decision maker	78.54601	135.1736	0.58	0.562	.0378042
Risk self-assessment score	-14.05217	43.43119	-0.32	0.747	-.0251873
Importance of irrigation	-33.03485	114.7209	-0.29	0.774	-.0226057
Constant	437.0539	988.5372	0.44	0.659	.

Source: Own survey, 2014, Stata output

Appendix B

Table B1: Logistic Regression Results for Choice Set 4

Logistic regression	Number of obs	=	300
	LR chi2(3)	=	4.33
	Prob > chi2	=	0.2282
Log likelihood = -177.57819	Pseudo R2	=	0.0120

Choice Set 4	*Odds Ratio*	*St. Err.*	*z*	*P>|z|*	*95% Confidence Interval*	
Net per capita income	1.000173	.000593	0.29	0.770	.9990116	1.001336
Elevation	1.000737	.0004551	1.62	0.105	.9998453	1.001629
Gender of decision maker	1.452345	.3960071	1.37	0.171	.8510892	2.478362
Constant	.1447721	.0853718	-3.28	0.001	.0455757	.4598716

Source: Own survey, 2014, Stata output

Table B2: Logistic Regression Results for Choice Set 6

Logistic regression	Number of obs	=	300
	LR chi2(3)	=	1.30
	Prob > chi2	=	0.7296
Log likelihood = -207.28841	Pseudo R2	=	0.0031

Choice Set 6	*Odds Ratio*	*St. Err.*	*z*	*P>|z|*	*95% Confidence Interval*	
Net per capita income	.9998764	.0005303	-0.23	0.816	.9988376	1.000916
Elevation	1.00041	.000386	1.06	0.288	.9996535	1.001167
Gender of decision maker	.9947646	.248815	-0.02	0.983	.6092759	1.624152
Constant	.6173254	.3042734	-0.98	0.328	.2349446	1.622044

Source: Own survey, 2014, Stata output

Appendix C

Figure C1: Traditional Three-Stone Stove

Photo by: Ripple Africa

Figure C2: Clay Stove (*Chitetezo Mbaula*)

Photo by: Stefan Meyer

Figure C3: Rocket Stove

Photo by: RocketWorks

Appendix D

Figure D1: Dedza District, geographical context

Source: Google Earth

Figure D2: Dedza District, political map

(following page)

Source: G.A. Naliya, NSO Zomba

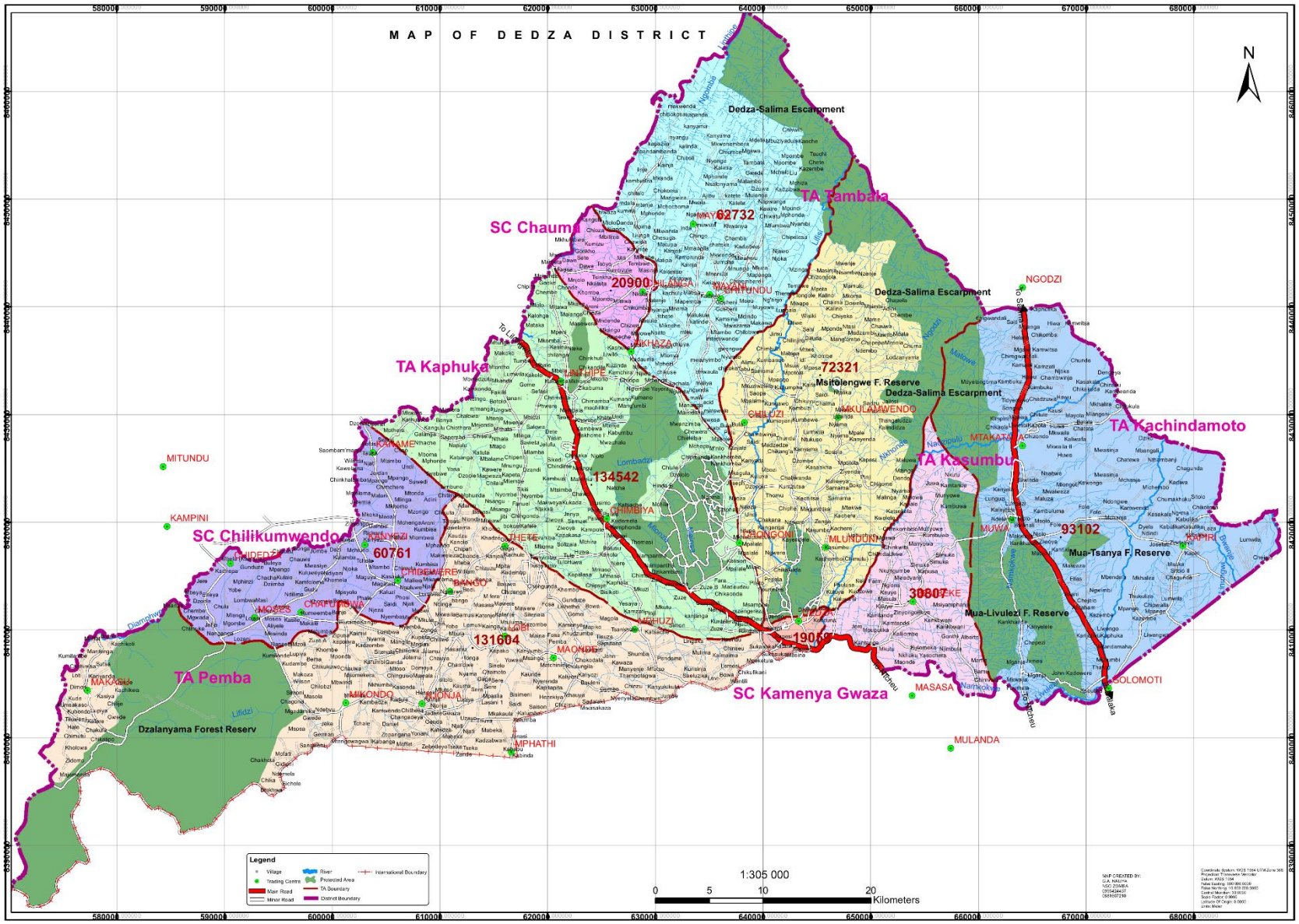
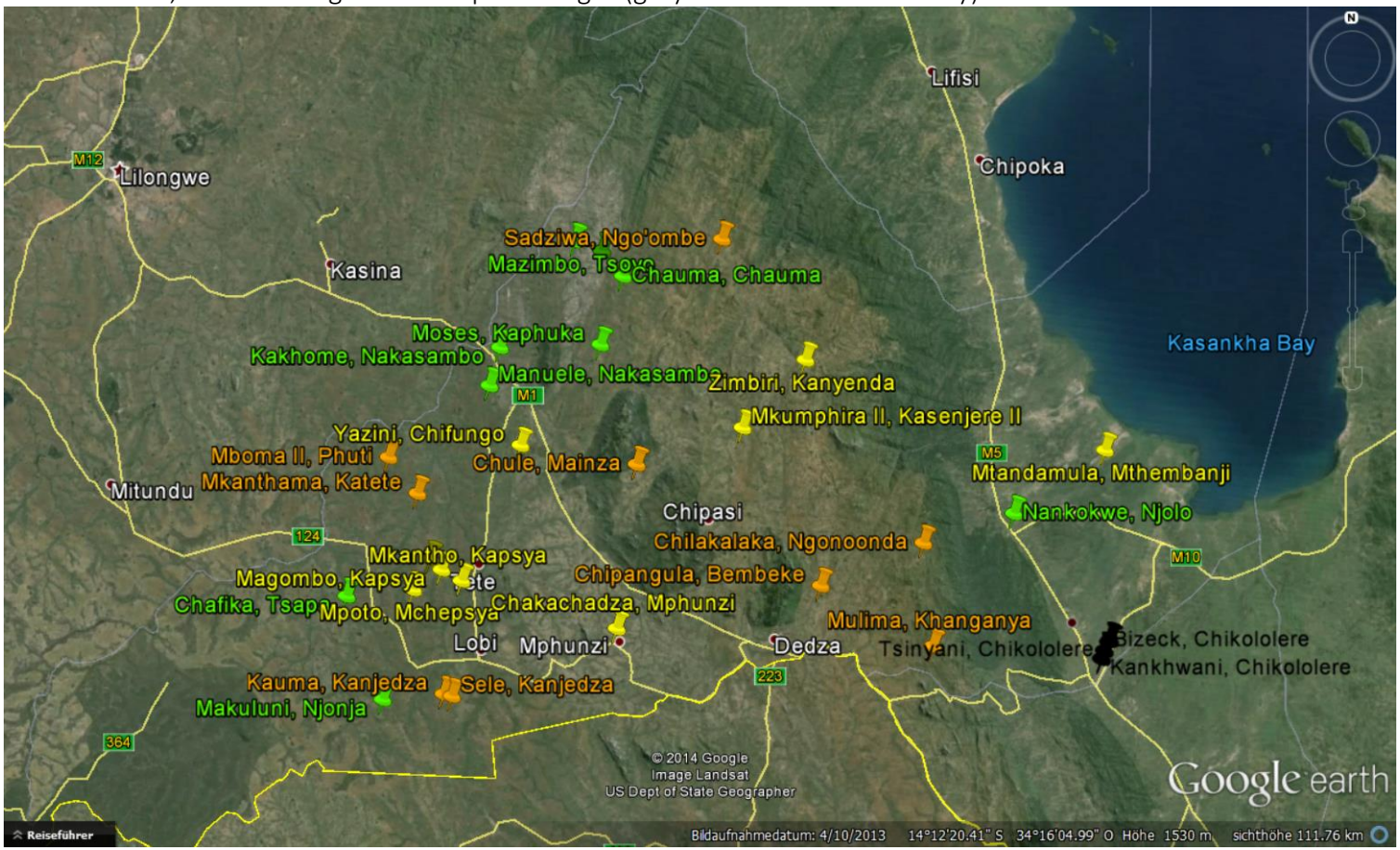

MAP OF DEDZA DISTRICT
N
Dedza-Salima Escarpment
TA Tambala
SC Chauma
62732
20900
NGODZI
TA Kaphuka
72321
Msitolengwe F. Reserve
Dedza-Salima Escarpment
TA Kachindamoto
MITUNDU
134542
TA Kasumbu
KAMPINI
SC Chilikumwendo
93102
60761
Mua-Tsanya F. Reserve
30807
Mua-Livulezi F. Reserve
131604
190600
TA Pemba
SC Kamenya Gwaza
MASASA
SOLOMOTI
MULANDA
Dzalanyama Forest Reserv
Legend
Village
Trading Centre
Main Road
Minor Road
River
Protected Area
TA Boundary
District Boundary
International Boundary
1:305 000
0 5 10 20
Kilometers

Figure D3: Dedza District, satellite image with sampled villages (grey line is district boundary)



Source: Google Earth

Appendix E

E1: The Cook Stove Choice Experiment (Mayesero osankha *Mbaula)*

This morning during the group meeting, we discussed two types of improved cook stoves: the chitetezo mbaula (made of clay), and the rocket stove (made of metal). Please assume that you have access to both types of stoves and answer the following questions about your stove preferences. For each question there are only two alternatives, if you do not like either alternative, please choose the one that you dislike least. *Pa msonkhano wathu kummawa kuja, tinakambiranako za mitundu iwiri ya mbaula zamakono: mbaula ya chitetezo (yadothi) ndi mbaula ya roketi (yachitsulo). Pano, ndikufuna ndikufunsenkoni zamakonda anu pa mbaula zamakonozi, titati tiyerekeze kuti inu muli ndi mwayi oti mutha kupeza mbaulazi. Pa chisankho chilichonse, pali njira ziwiri zoti musankhepo koma ngati simungazikonde njira zonsezi, mundiuzebe chisankho chimene mutha kuchikondako pang'ono.*

Choice Set *(Zisankho)*	Alternative 1 *(Njira yoyamba)* (0=did not select, 1=selected)	Alternative 2 (*Njira yachiwiri)* (0=did not select, 1=selected)
Block 1		
1		
2		
3		
4		
5		
6		
7		
8		
9		
Block 2		
10		
11		
12		
13		
14		
15		
16		
Block 3		
17		
18		
19		
20		
21		

22		
23		
24		

E2: The Subsidy Policy Preference CE

This morning during the group meeting, we discussed two hypothetical types of subsidy: a cash payment (which your HH may spend on any items that it chooses), and a fertilizer subsidy (in the form of NPK coupons). Both of these are conditional upon adoption of agroforestry practices, for example planting tephrosia or msangu among your crops. Please answer the following questions about your subsidy preferences. For each question there are only two alternatives, if you do not like either alternative, please choose the one that you dislike least. *Pa msonkhano wathu kummawa kuja, tinakambiranakonso za mitundu iwiri ya sabuside koma yongoganizira; sabuside ya kulandira ndalama (zomwe banja lanu litha kugwiritsa ntchito pa china chilichonse chomwe mungakonde) ndi sabuside ya feteleza (yolandira ma kuponi a feteleza wa chitowe). Kumbukirani kuti ma sabuside onsewa ndi otheka pokhapokha mutadzala ndi kusamalira mitengo yobwerezeretsa chonde m'nthaka, monga tephrosia, kesha ndi msangu, mmunda mwanu. Pano ndikufuna ndikufunsenkoni za zisankho zomwe mngapange pa ma sabuside amenewa. Pa funso lililonse, pali njira ziwiri zoti musankhepo koma ngati simungazikonde zisankhozi, mundiuzebe chisankho chimene mutha kuchikondako pang'ono.*

Choice Set (*Zisankho)*	Alternative 1*(Njira yoyamba)* (0=did not select, 1=selected)	Alternative 2 *(Njira yachiwiri)* (0=did not select, 1=selected)
1		
2		
3		
4		
5		
6		
7		

If the respondent preferred Alternative 2 (fertilizer) in every choice set, ask the following *(ngati omwe mukucheza nawo asankha njira yachiwiri (feteleza) pa mafunso onse, afunseni funso lotsatirali*:

8 Why do you prefer a fertilizer subsidy over a cash transfer even when the cash transfer is worth significantly more?[8] (list reasons in order, most important first) *Nchifukwa ninji inu mwasankha sabuside ya feteleza osati kulandira ndalama ingakhale mu mafunso amene ndalama zinali zochulukirapo?[8] (perekani zifukwa mwandondomeko, kuyambira chofunikira kwambiri)*

E3: Land Use and Ownership (Kagwiritsidwe ntchito ka malo ndi umwini wa malowo)

I will now ask about your land parcels from agricultural year 2012/2013 (which is defined as November 2012 to October 2013) and ownership status. *(Mugawo ili ndikufuna tichezeko zokhuzana ndi malo amene munagwiritsa ntchito mu chaka cha ulimi cha 2012/2013 (kuyambira Novembala, 2012 kufikira Okotobala, 2013) komanso zaumwini wamalowo).*

A parcel is a contiguous piece of land that has a common owner, land rights and tenure status.

		Parcel (malo) #1	Parcel (malo) #2	Parcel (malo) #3	Parcel (malo) #4	Parcel (malo) #5	Parcel (malo) #6	Parcel (malo) #7
1	Parcel Name *(Dzina la malo)*							
2	What is the area of the parcel *(Malowo ndi akulu bwanji)?* (acres)							
3	What is this parcel used for?[3] (cropland, forest land, etc. If it is used by another household please code accordingly: leased out, share cropped out, etc.) *(Kodi malowa munawagwiritsa ntchito yanji?)*							
4	How was this parcel acquired *(Kodi malowa munawapeza bwanji)?*[4]							
5	What year will this agreement end *(Mgwirizano wamalowa uzatha chaka chanji)?* (years) (-777=I don't know, -999=will have forever) (if -999>>7)							
6	If not forever, why not *(Nchifukwa ninji mgwirizanowu siwamuyaya*)?[6]							

		Parcel #1	Parcel #2	Parcel #3	Parcel #4	Parcel #5	Parcel #6	Parcel #7
	What was the distance in walking minutes from the parcel to (*Munkayenda nthawi yaitali bwanji (min) kuchokera ku malowa kufika ku _____*:							
7	Nearest all-weather road *(passable by vehicle all year round) Msewu omwe umadutsika ndi galimoto munyengo zonse*?							
8	Nearest seasonal road *(passable by vehicle part of the year) Msewu omwe sumadutsika ndi galimoto munyengo ina yapachaka*?							
9	Nearest Market *(where you could sell any crops) Msika wapafupi (omwe munakatha kukagulitsako mbewu zina zilizonse)*?							
10	The closest natural water source for irrigation/ watering that you apply to this parcel during the **dry season** (*river, lake, well, natural spring, NOT water pump or canal or bore hole or other man-made water source)*? *Malo apafupi achilengedwe omwe mumakapezako madzi ogwiritsa ntchito paulimi othilira pamalowa munyengo **yachilimwe** (monga nyanja, m'tsinje, chitsime, kasupe koma osati pampu, m'jigo kapena njira zina zopangidwa ndi munthu)*							
11	The closest natural water source for irrigation that you apply to this parcel during the **rainy season** *(river, lake, well, natural spring, NOT water pump or canal or bore hole or other man-made water source)*? *Malo apafupi achilengedwe omwe mumakapezako madzi ogwiritsa ntchito paulimi othilira pamalowa munyengo **yadzinja** (monga nyanja, m'tsinje, chitsime, kasupe koma osati pampu, m'jigo kapena njira zina zopangidwa ndi munthu)*							

E4: Cropland Management Practices (Njira zogwiritsa ntchito ndi kusamalira malo olima)

A plot is a contiguous piece of land in a parcel that has the same cropping system or land use. This means a parcel could also be a plot if it has the same cropping system or land use throughout.

E4.1: Plot Level Land Management and Labor Input

The following questions refer to your plots in the 2012/2013 agricultural year. *(Mafunso otsatirawa akutengera zigawo zomwe zinalimidwa mu chaka cha ulimi cha 2012/2013)*

		1	2	3	4	5	6
Parcel (*Malo*) #	Plot (*Chigawo*) #	Which crops were grown on this plot *(Munadzalapo mbewu zanji pachigawochi)?*[1] (one crop per row)	How much of this crop was harvested from this plot in 2012/2013 (*Munakolorapo mbewu yochuluka bwanji pachigawochi mu chaka cha 2012/2013*)? (amount)	Unit[3]	How much of this crop from this plot was sold in 2012/2013? (Pa zomwe munakolora pa chigawochi, ndi mbeu yochuluka bwanji yomwe munagulitsa mu chaka cha 2012/2013)? (amount)	Unit[3]	How much money did you receive for the amount of crop that was sold (*Pazomwe munagulitsazo, munapezapo ndalama zochuluka bwanji*)? (kwacha)

		7	8	9	
Parcel (*Malo*) #	Plot (*Chigawo*) #	What was the total area of the plot (*Chigawochi chinali chachikulu bwanji)*? (acres)	How many labor days were hired in total in 2012/2013 for work on this plot? *(prompt respondent with land preparation, planting, weeding, fertilizer application, harvest activities) (Ndi masiku ochuluka bwanji omwe aganyu anagwirapo ntchito pa chigawochimu chaka cha 2012/2013?* (if "0">>10)	How much did you pay in total per year for hired labor for this plot *(Munawalipira ndalama zingati (zonse pa chaka) aganyu amene anagwira ntchito pachigawochi)*?	
				kwacha	In-kind (kwacha value)

E4.2: Seeds, Irrigation and Agrochemicals (Mbewu, Ulimi wamthilira ndi Mankhwala a mbewu)

		10	11	12			13			14		
Parcel #	Plot #	How important is access to irrigation technology for obtaining output (yield) on this plot?[10] *Ndikofunikira bwanji kupeza njira zopangira ulimi wamthilira kuti mupeze zokolora pa chigawochi?*	What share (%) of the plot was irrigated? (if 0>>17) *(Ndi malo aakulu bwanji (peresenti) a chigawochi omwe munapangapo ulimi wamthilira?)*	Which irrigation technologies were used on this plot? [12] (list top three, most important first). (*Ndi njira ziti zaulimi wamthilira zomwe munagwiritsa ntchito pachigawochi?)*			How many times per month was this plot irrigated by each technology during the **dry** season *(Munyengo **yachilimwe,** munathiririra kangati pamwezi pogwiritsa ntchito njira **[iyi]** ya ulimi wamthilira*)?			How many times per month was this plot irrigated by each technology during the **rainy** season *(Munyengo **yadzinja,** munathiririra kangati pamwezi pogwiritsa ntchito njira **[iyi]** ya ulimi wamthilira*)?		
				1	2	3	1	2	3	1	2	3

		15	16	17
Parcel #	Plot #	If canal irrigation is used (if not>>17), what is the distance in walking minutes from the plot to the part of the canal that you use during the **dry season *(Ngati amagwiritsa ntchito ngalande),*** *mumayenda mphindi zingati kuchoka kuchigawochi kukafika pa ngalande yomwe mumagwiritsa ntchito pa ulimi othilira mu nyengo ya **chilimwe***?	If canal irrigation is used, what is the distance in walking minutes from the plot to the part of the canal that you use during the **rainy season *(Ngati amagwiritsa ntchito ngalande),*** *mumayenda mphindi zingati kuchoka kuchigawochi kukafika pa ngalande yomwe mumagwiritsa ntchito pa ulimi othilira mu nyengo ya **dzinja***?	Which type of chemical fertilizer did you apply to this plot **(if more than one, separate by comma)** *(Munathira feteleza wanji pa chigawochi?)*[17]

		18		19	20
Parcel #	Plot #	How much chemical fertilizer did you apply to this plot? (*Munathirapo feteleza wochuluka bwanji pa chigawochi*)?		What is the total cost of all purchased agrochemicals (excluding fertilizer) that you applied to this plot? **(kwacha)** *Munaononga ndalama zochuluka bwanji (zonse pamodzi) kugulira mankhwala ena (kupatula feteleza) omwe munathira pa chigawochi?*	What is the total cost of all purchased other inputs that you applied to this plot? **(kwacha)** *Munaononga ndalama zochuluka bwanji (zonse pamodzi) kugulira zipangizo zina zaulimi zomwe munagwiritsa ntchito pa chigawochi?*
		Amount	Unit[3]		

E4.3: Agroforestry, Soil Fertility Management, Conservation Agriculture (Kudzala mitengo yobwezeretsa chonde m'nthaka, kasamalidwe ka chonde m'nthaka, ulimi wa mtaya khasu)

		Did you practice ___ on this plot in 2012/2013? (0=no, 1=yes) (*Kodi munadzalako/munathirako _____ mu chaka chaulimi cha 2012/2013?*									
		21	22	23	24	25	26	27	28	29	30	31
Parcel (*Malo)* #	Plot # (*Chigawo)*	Scattered trees *(mitengo yosakhala mu ndondomeko)*	Leguminous plants in boundaries *(mbewu za gulu la nyemba m'mbali mbali mwa munda)*	Alley cropping *(kudzala mbeu ndi mitengo yopezetsa ndalama ngati macademia)*	Msangu	Cassia	Tephrosia	Livestock Manure *(Ndowe)*	Green Manure *(Manyowa)*	Night manure *(Manyowa akuchimbudzi)*	Crop residue *(zotsalira zamunda e.g. masangwe, mapesi)*	Household refuse *(zinyalala za panyumba)*

		Did you practice ___ on this plot in 2012/2013? (*kodi munadzalako/munapangako _____ mu chaka chaulimi cha 2012/2013?)* (0=no, 1=yes)									
		32	33	34	35	36	37	38	39	40	41
Parcel #	Plot #	Intercropping *(kulima mbewu mosakaniza)*	Minimal/zero tillage *(ulimi osapanga mizere)*	Deep tillage *(ulimi opanga mizere)*	Contour farming *(ulimi wa akalozera)*	Trenches/ridges *(ulimi okumba mayenje m'munda)*	Box ridges *(ulimi opanga mizere ya mabokosi)*	Terraces *(kulima mizere yolinganapa chitunda)*	Grass strips (eg. Vertivar) *(kudzala udzu wa vetiva)*	Compost *(kompositi)*	Cover crops *(mbeu zoyanga)*

E4.4: Cultivation, Harvest and Transport Tools/Machinery (Zida zogwiritsa ntchito; polima, pokolola ndi kunyamula zokolola)

		42	43
Parcel *(Malo)* #	Plot (*Chigawo*) #	What was the total cost per season to hire tools used for **cultivation and harvest** (*Munalipira ndalama zochuluka bwanji popanga hayala chipangizochi pachaka)*? (kwacha)	What was the total cost per season to hire tools used for **transport** (from field to home or storage area to market) these (*Munalipira ndalama zochuluka bwanji popanga hayala chipangizochi pachaka)*? (kwacha)

E5: Input Access (Kupezeka kwa zipangizo zina ndi zina zogwiritsa ntchito paulimi)

Please tell me about your access to inputs (*Mu gawo ili, ndikufuna tichezeko zokhudzana ndi mmene mumapezera zipangizo zina ndi zina zogwiritsa ntchito paulimi)*.

		FISP inputs *(Zipangizo zaulimi za sabuside (zotsika mtengo)*			
		FISP fertilizer (NPK) (*Feteleza wa sabuside wa Chitowe).*	FISP fertilizer (urea) (*Feteleza wa sabuside wa yureya)*	FISP maize seeds *(Mbewu ya chimanga ya sabuside)*	FISP legume seeds (*Mbewu za sabuside zagulu lanyemba*)
1	Which FISP coupons were you eligible for in agricultural year 2012/2013 (*Kodi inu munali ndi **zokuyenerezani** kulandira nawo ma kuponi a feteleza ndi mbewu mu chaka cha 2012/2013)*? (0=not eligible, 1=eligible, 2=not sure)				
2	How much subsidized input did you get with your share of the coupon (*Munakwanitsa kupeza feteleza/mbewu za sabuside zochuluka bwanji pogwiritsa ntchito kuponi yanu)*? (kg)				
3	Did you get the subsidized input in the full amount allowed by your share of the coupon (*Kodi munapeza feteleza/ mbewu yokwanira monga mwa mlingo umene mumayenera kuti mupeze pogwiritsa ntchito kuponi yanu)*? (0=no (I got less than expected*)*? (0=no (I got less than expected), 1=yes)				
4	Did you pay anyone, either in cash or in-kind, to obtain an input coupon for this input (*Kodi munalipirako aliyense kuti mupeze kuponi ya chipangizo cha ulimichi)*? (0=no, 1=yes) (if "0">>6)				
		FISP NPK	FISP urea	FISP maize seed	FISP legume seed

5	If yes, how much did you pay (*Ngati munalipira, munalipira ndalama zingati)*? (kwacha and/or in-kind kwacha value)				
6	Did you use a coupon to buy the full amount of the input that you needed (*Kodi munakwanitsa kupeza mlingo wa feteleza/mbewu imene imafunika pa ulimi wanu pogwiritsa ntchito kuponi yanu)*? (0=no, 1=yes, 2=both with and without coupon)				
7	What price per kg did you pay **with** the subsidy coupon (*Kodi munalipira ndalama zingati pa kilogalamu pogula feteleza/mbewu zotsika mtengo)*? (kwacha) (-999=not sure)				
8	If you hadn't used the coupon, what would have been the price per kg at the time when you used the coupon (*Mukanakhala kuti simunagwiritse kuponi, mtengo wa feteleza/mbewuyi pa kilogalamu pamsika unali ndalama zingati)*? (kwacha per kg) (-777=don't know)				
9	What did you do with the subsidized input? (1=used on own farm, 2=shared with other farmer(s) for free, 3=sold it) *(Kodi munapanga nacho chani chipangizo cha ulimi chotsika mtengo chomwe munapeza)*				

E6: Non-Crop Income *(Ndalama zopezeka kuchokera ku ulimi wa ziweto)*

Now I will ask you about livestock and livestock products that you sold in agricultural year 2012/2013. *Pano tichezako za ziweto ndi zinthu zochokera ku ziweto zomwe munagulitsa mu chaka cha ulimi cha 2012/2013.*

	1	2	3	4	5	6
	Did your HH raise (these animals) in 2012/2013? (0=no, 1=yes, if no>>next animal) *(Kodi munawetako ziweto izi pakhomo panu mu chaka cha 2012/2013?*	Did your HH sell **products** (meat, milk, eggs, skins, etc.) from (these animals) in 2012/2013? (0=no, 1=yes, if no>>4) (*Kodi munagulitsa zinthu izi (nyama, mkaka, mazira, zikumba ndi zina zilizonse zochokera ku ziwetozi) mu chaka cha 2012/2013?*	What was the total revenue (not accounting for costs incurred) that your HH received for sales of **products** from (these animals) in 2012/2013? (kwacha) (*Kodi munapeza ndalama zochuluka bwanji zonse pamodzi (osawerengara zimene munaononga) pogulitsa zinthu zochokera ku ziwetozi mu chaka cha 2012/2013?*	How many of (these **live** animals) did your HH sell in 2012/2013? (if "0">>6) *(Kodi munagulitsa ziweto zingati zamoyo mu chaka cha 2012/2013?*	What was the total revenue (not accounting for costs incurred) that your HH received for sales of (these **live** animals) in 2012/2013? (kwacha) *(Kodi munapeza ndalama zochuluka bwanji zonse pamodzi (osawerengara zimene munaononga) pogulitsa ziwetozi mu chaka cha 2012/2013?*	What were the total costs incurred (purchasing animal, vaccinations, feed, building shelter) from raising (these animals) in 2012/2013? (kwacha) *(Kodi munaononga ndalama zochuluka bwanji zonse pamodzi (pogulira; ziwetozi, katemera, chakudya ndikumanga khola la ziwetozi) mu chaka cha 2012/2013)?*
Cattle *(ng'ombe)*						
Goats *(mbuzi)*						
Sheep *(nkhosa)*						

Chickens
(nkhuku)

Pigs
(nkhumba)

Other animals (specify)
(ziweto zina)

_____

Other animals (specify)
(ziweto zina)

_____

Other animals (specify)
(ziweto zina)

_____

	7	8	9
	Did your HH earn income (cash or in-kind) from (source) in 2012/2013? (0=no, 1=yes, if no>>next source) *(Kodi munapangako ndalama kapena kulandira zinthu zina kuchokera ku _____ mu chaka cha 2012/2013?*	What was the total revenue (not accounting for costs incurred) from (source) in 2012/2013? (kwacha) *(Kodi munapeza ndalama zochuluka bwanji zonse pamodzi (osawerengara zimene munaononga) kuchokera ku_____ mu chaka cha 2012/2013?*	What were the total costs incurred from generating (source) in 2012/2013? (kwacha) *(Kodi munaononga ndalama zochuluka bwanji (zonse pamodzi) kuti mupeze _____ mu chaka cha 2012/2013)?*
Forest/agroforestry products (like wood, charcoal, medicinal plants, etc.) *(Nkhalango ndi zinthu zina zochokera ku mitengo yobwezeretsa chonde mthaka) (monga: nkhuni, matabwa, makala, mankhwala a zitsamba ndi zina zotero)*			
Fishery/acquaculture products *(Nsomba ndi zinthu zina za mmadzi)*			
Wildlife products (mice, bush meat, wild skins, etc.) *(nyama za mtchire monga mbewa, insa, gwape, ndi zikumba za nyam za mtchire)*			
Agricultural wage *(maganyu a kumunda)*			
Non-agricultural wage *(maganyu ena osakhala a kumunda)*			
Non-agricultural business (shops, handicrafts, etc.) *(Bizinesi osakhala ya ulimi (monga mashopu, ntchito zamanja)*			
Government aid *(Chithandizo chochokera ku boma)*			
Non-governmental aid *(Chithandizo china chosakhala chochokera ku boma)*			
Retirement payment *(Malipiro opumira pantchito)*			
Remittances/gifts *(Mphatso)*			

Mutual support groups (local community) (*Magulu ena othandizana a mmudzi)*			
Other source of income, please specify *(Njira zina zopezera ndalama)* _____			
Other source of income, please specify *(Njira zina zopezera ndalama)* _____			

E7: Hypothetical Cash Transfer Program *(Pologalamu yongoganizira yolandira ndalama kuchokera ku boma)*

Now we ask for your thoughts on a different **hypothetical** cash payment from the government. If your HH were to receive a one-time cash transfer of 42,000.00 Kwacha from the government next week, what would you do with this money? (*Pano ndikufuna ndimveko maganizo anu pa nkhani inanso yongoganizira yolandira ndalama kuchoka ku boma. Mongoganizira, atati khomo lanu lilandire ndalama yokwana 42, 000 Kwacha mwa kamodzi kuchokera ku boma, inu ndalama imeneyi mungapangire chani?)* (Enumerator note: let the respondent tell you what they would spend, do not prompt them with the categories, then once they have told you the items, categorize them yourself)

1 Please list in order (most important first) the top three things you would spend this money on:[1]

E8: Irrigation (Ulimi othilira)

Please tell me about the irrigation that you do and do not use, and answer some questions about your irrigation preferences (*Mu gawo ili, ndikufuna tichezeko za njira za ulimi wothilira zomwe mumagwiritsa ntchito kapena simugwiritsa ntchito. Komanso, ndikufuna ndidziweko za maganizo anu pa njira ndi zipangizo zimene zimagwiritsidwa ntchito pa ulimi othilira).*

		Bucket/watering can	Treadle pump	Motorized pump	Canal/gravity fed	Drip irrigation	Bound basin flood (paddy)	Other (specify) _____
	Using the responses from Section 3-B, #9, mark which irrigation technologies were used in agricultural year 2012/2013 (Kugwiritsa ntchito mayankho amu Section 3-B, #9, lembani njira zomwe khomoli/banjali linagwiritsa ntchito pa ulimi othilira muchaka cha ulimi cha 2012/2013) *(0=not used, 1=used)*							
1	For those that **were not used**, why didn't your HH use them (if multiple reasons, list in order, most important first, separated by commas) (***Panjira zomwe sizinagwiritsidwe ntchito,*** *nchifukwa ninji inu simunazigwiritse ntchito)*?[1]							
2	For those that **were used**, where did your HH obtain them (***Pa njira zomwe zinagwiritsidwa ntchito****, munazipeza kuti/bwanji)*?[2]							
3	When was (this technology) obtained (*Kodi njira imeneyi munaipeza chaka chanji)*? (year)							
		Bucket/watering can	Treadle pump	Motorized pump	Canal/gravity fed	Drip irrigation	Bound basin flood (paddy)	Other (specify) _____

4	How much was the purchase price (or your HH's contribution to the purchase price) (*Ngati inagulidwa, munagula ndalama zingati (Kapena inu munasokhako ndalama zingati pogulira njira imeneyi)*? (kwacha)							
5	How much did your HH pay in total in agricultural year 2012/2013 to maintain the technology (*Mu chaka cha ulimi cha 2012/2013 munaonongako ndalama zokwana zingati posamalira njira imeneyi)*? (kwacha)							
6	Does your HH have sole use of this technology or is it shared (Kodi n*jirayi imagwiritsidwa ntchito ndi khomo lanu lokha kapena ndi yogawana ndi anthu ena)*? (0=not shared, 1=shared)							
7	Who manages this irrigation technology in your village (*Mudzi mwanu muno amayang'anira njira imeneyi ndi ndani)*?[7]							
8	Do you think the distribution of water among members of the community was managed fairly *(Mukuganiza kuti kagawidwe kamadzi othilirira pakati pa anthu a m'mudzi mwanu muno kanachitika mwachilungamo)*?[8]							
9	How often did you experience a shortage of irrigation water (*Kodi mavuto amadzi othilirira munakumana nawo kochuluka bwanji)*?[9]							

For this next segment, I would like to ask about your willingness to contribute to a hypothetical new irrigation scheme for your village. In this case, all contributions of time, labor and management would be unpaid. Maintenance would need to be done to keep the scheme in working condition; maintenance activities may include: cleaning equipment to prevent water blockage and repairing damaged equipment. Management of the scheme would include voting to elect water committee members, attending meetings, deciding on fair distribution schedules, and distributing the water. *(Mu gawo ili, ndikufuna tichezeko zokhudzana ndi kukonzekera kwanu kuperekako zofunikira zina ndi zina za sikimu ya ulimi othilirira yongoganizira yatsopano ya mudzi mwanu. Apa, ndikufuna ndidziweko za kukonzeka kwanu kuperekako; nthawi, mphanvu zanu ndi kusamalira sikimuyi mwaulere. Dziwani kuti muli oyenera kukonza sikimuyi kuti ikhale yogwira ntchito ndipo kusamala kwake ndi kupanga zinthu monga: kutsuka zipangizo zogwiritsa ntchito kuopetsa kutsekeka kwa njira yodutsamo madzi ndi kukonza zipangizo zomwe zaonongeka. Kuyendetsa sikimuyi ndi kupanga zinthu monga: kuvotera a komiti, kukhala nawo pa misonkhano, kupanga ziganizo za magawidwe a madzi ndi kugawana madzi othilirira).*

	If, <u>hypothetically,</u> the government were planning to develop an irrigation scheme for communal use in your village… (*<u>Mongoganizira,</u> boma likuganizira zomanga sikimu ya ulimi othilira yogwiritsidwa ntchito ndi anthu onse a m'mudzi mwanu…*)	Treadle pump	Motorized pump	Canal/gravity fed	Drip irrigation	Bound basin flood (paddy)	Other (specify) _____
10	Which technologies would you prefer? (*Ndi njira ziti za ulimi othilira zomwe mungakonde?)* (Rank all technologies listed in order, 1=most preferred, 2=next preferred…) (-999=not applicable to this village)						
11	On average, how much time per week would you be willing to work on the **construction** of the scheme of this irrigation type? *(Mungalore kupereka nthawi yochuluka bwanji **pomanga** sikimuyi pa sabata)?* (hours per week)						
12	In total, how much money would you be willing to contribute to the **construction/purchase** of the scheme of this irrigation type? *(Mungalore kuperekako ndalama zochuluka bwanji zothandizira **kumanga/kugula** sikimuyi/kapena njira ya ulimi othilirayi)?* (kwacha)						

	Once this (scheme) were built… ***(Sikimuyi itakhala kuti yamangidwa…)***	Treadle pump	Motorized pump	Canal/gravity fed	Drip irrigation	Bound basin flood (paddy)	Other (specify) _____
13	On average, how much time per year would you be willing to work as a volunteer (unpaid) on the **maintenance** of the scheme of this irrigation type? *(mungakhale okonzeka kumaononga nthawi yochuluka bwanji pachaka* ***posamalira*** *sikimuyi mwaulere)* (hours per year)						
14	How much money would you be willing to contribute annually to the **maintenance** of the scheme of this irrigation type? *(Mungakhale okonzeka kumaononga ndalama zochuluka bwanji pachaka* ***posamalira*** *sikimuyi)?* (kwacha)						
15	On average, how much time per year would you be willing to volunteer (unpaid) to contribute to the **management** of the scheme of this irrigation type? *(Mungakhale okonzeka kumaononga nthawi yochuluka bwanji pachaka* ***poyendetsa*** *sikimuyi mwaulere)?* (hours per year)						
16	How much money would you be willing to contribute per year to the **management** of the scheme of this irrigation type? *(Mungakhale okonzeka kumaononga ndalama zochuluka bwanji pachaka* ***poyendetsa*** *sikimuyi)?* (kwacha)						

E9: Risk Taking

Note to enumerators: It is very important in this section to NOT give examples. Just explain as stated below and allow the respondent to interpret the question in their own way.

		Show scale from Code Sheet and have respondent point anywhere along the scale, record number:
1	How do you see yourself: Are you **generally** a person who is fully prepared to take risks or do you try to avoid taking risks? Please rank yourself from a scale of 0 to 9 with 0 as fully avoiding risks and 9 as fully prepared to take risks. (*Mumadziona bwanji: Kodi ndinu munthu wokonzeka kukumana ndi chiopsezo kapena mumapewa kutenga ziopsezo? Ndikufuna mundionetse pamene pali mulingo wanu wachiopsezo pa sikelo yoyambira 0 kulekeza 9, pamene pa 0 ndipopewa ziopsezo kwambiri ndipo pa 9 ndipokonzeka kutenga chiopsezo)*	

E10: Household Dietary Diversity *(Zakudya zakasinthasintha)*

For this section about your household's eating habits, I need to please ask the questions to the member of your household who regularly prepares the food. *(Mugawo ili ndikufuna ndicheze nanu zamadyedwe a panyumba panu.)*

		PID
1	Who is most responsible for food preparation in your household? (*Kodi amakonza chakudya pakhomo pano ndi ndani nthawi zambiri? (*person answering this section)	

Enumerator: if the main agricultural decision maker is NOT the person who regularly prepares food, skip this section.

	In the last 24 hours, have you or any member of your household eaten the following foods (this includes food eaten outside the house, for example lunch in the field or dinner at a friend's house) (if there was a special event in the last 24 hours, likea wedding or big party, then recall for the preceding day): *(Kodi mumaola 24 apitawa, inuyo kapena wina wapakhomo lanuli wadyako zakudya monga):*	0=no, 1=yes
2	Any nsima, bread, noodles, biscuits, or any other foods made from millet, sorghum, maize, rice or wheat (*Nsima, buledi, nudozi, bisiketi, kapena Zakudya zilizonse zochokera kumapira, mawere, chimanga, mpunga kapena tirigu*)?	
3	Any potatoes, yams, cassava, or other foods made from roots or tubers (*Mbatata, mbatatesi, chinangwa, kapena chakudya chochokera ku mizu*)?	
4	Any vegetables *(zamasamba)?*	
5	Any fruits (*zipatso*)?	
6	Any goat, chicken, beef, pork, duck, other birds, game, mice, monkey, liver, kidney, heart or other meats (*Nyama ya mbuzi, nkhuku, ng'ombe, nkhumba, bakha, mbalame, nyama zakutchire, mbewa, anyani, ndi nyama zamitundu ina)?*	
7	Any eggs (*mazira*)?	
8	Any fresh or dried fish or shellfish (*Nsomba zouma kapena zafuleshi*)?	
9	Any foods made from beans, soy beans, peas, lentils or nuts? (*Zakudya zopangidwa kuchokera kunyembe, soya, sawawa, kalongonda kapena mtedza*)	
10	Any cheese, yoghurt, milk, or other milk products (*mkaka, chakudya chochokera ku mkaka monga yogati, chambiko*)	
11	Any foods made with oil, fat or butter (*Zakudya zochokera kumafuta*)?	
12	Any sugar or honey (*shuga kapena uchi*)?	
13	Any other foods, such as condiments, coffee, tea (*Zakudya zina monga zokometsera ndiwo, khofi, tiyi*?	

	14	15	
	Last week, how many times did the following people in your HH have beans, peas, soy beans or lentils with a main meal (*mu sabata yapitayi, anthu awa amadya kangati nyemba, sawawa, soya ndi ndiwo zina zamgulu lanyemba pamodzi ndi nsima*)?	What was the average size of one of these bean/pea/lentil portions (*Kodi chakudyachi chimakhala chamlingo wochuluka bwanji*)?	
		Amount	Unit[15]
Male adults			
Male children			
Female adults			
Female children			

16	In the previous year, how frequently did you experience food shortages *(Ndikangati munakhala opanda chakudya mchaka chapitachi*)?[16]	

E11: Fuel Use and Access (Kagwiritsidwe ntchito ndi kapezedwe ka zokolezera moto)

This part of the questionnaire is about the types of fuel your household uses and the access you have to them, (*Gawo lino ndiyokhudzana ndi zinthu zomwe mumagwiritsa ntchito pokolezera moto pakhomo panu and kapezekedwe kake)*.

		PID
1	Which member of your HH is most knowledgeable about fuel use and access (*Ndi ndani nyumbamu amadziwa kwambiri zakagwiritsidwe ntchito ndi kapezedwe ka zinthu zokolezera moto)*?	

Enumerator: if the main agricultural decision maker is NOT the person who regularly uses and collects fuel, skip this section.

	2	3	4	5	6		7
	What were your main energy sources for cooking and heating in the last 12 months (Kodi mumagwiritsa ntchito zinthu ziti zokolezera moto pophikira ndikutenthetsera pakhomo panu mchaka chapitachi) [2]?	From which location did you obtain (this energy source) (zinthu zokolezera motozi mumazipeza kuti) [3]? (if separate locations are used for a significant amount of a fuel source then write info in a separate row)	How far away (one-way trip) is this location from your home in walking minutes (Kodi mumayenda phindi (min) zingati kuchoka pakhomo panu kukafika kumalo komwe mumapeza zokolezera motozi)? (minutes)	Did you buy or collect (this energy source) from this location (Zokolezera motozi mumagula kapena mumangotola komwe mumazipezako)? (1=purchase, 2=collect, 3=both purchase and collect, if 2>>8)	What quantity was purchased per month (Pamwezi mumagula zambiri bwanji)?		If the energy source was purchased, how much was spent per month (Mumagwiritsa ntchito za ndalama zingati pamwezi) (kwacha)?
					Amount	Fuel Unit Code[6]	
Rainy Season (nyengo ya dzinja)							
Main Source							
Second Main Source							
Dry Season (nyengo yachilimwe)							
Main Source							
Second Main Source							

	8						9						10										11	
	In **the past week** how many trips did (PID) spend in total gathering (this energy source) (*Musabata yapitayi **(ujeni)** anayenda maulendo angati kukatolera ndi kunyamula zokolezera motozi)*?						In the past week how much time did (PID) spend acquiring (this energy source) from the location? (include time spent going to the location, acquiring the source, returning home) (*Musabata yapitayi **(ujeni)** anatenga nthawi yochuluka bwanji potolera zinthu zokolezera motozi (kuphatikizapo popita, kutolera ndi pobwerera kunyumba)*						In the past week, how much of (this energy source) was acquired per trip by (PID) *(Musabata yapitayi, ndizokolezera moto zochuluka bwanji zinatoleredwa ndi **ujeni**)?*									If you were to sell (this energy source), how much would you receive? (kwacha per unit)	
	PID	# of trips	PID	# of trips	PID	# of trips	PID	Minutes	PID	Minutes	PID	Minutes	PID	Amount	Unit[6]	PID	Amount	Unit[6]	PID	Amount	Unit[6]	Kwacha	Unit[6]
Source 1																							
Source 2																							

E12: Cookstoves and Health *(Mbaula ndi Umoyo)*

For this section, I need to please ask the question to the household member who is mainly responsible for cooking. *Mu gawo lino, ndikufuna ndichezeko ndi munthu yemwe ali ndi udindo ophika chakudya pakhomo panu.*

		PID
1	Which HH member is mainly responsible for cooking? *Ndi ndani pakhomo panu yemwe ali ndi udindo ophika chakudya?*	

Enumerator: if the main agricultural decision maker is NOT the person who regularly prepares food, skip this section.

I will now ask you about improved cook stoves. During the meeting this morning we presented two types of cookstoves: the Chitetezo mbaula and the rocket stove. Remember that if the stoves are used correctly they can reduce fuel consumption, smoke inhalation (and respiratory diseases), eye infections and the frequency of burns. (*Mugawo ili ndikufuna tichezeko za mbaula zamakono. Pamsonkhano wathu kummawa kuja, tinafotokoza za mitundu iwiri ya mbaula: Chitetezo mbaula ndi mbaula ya loketi. Kumbukirani kuti mbaulazi zikazigwiritsidwa ntchito moyenera zimatha: kuchepetsa kuchuluka kwa zinthu zokolezera moto zomwe mumagwiritsa ntchito pophika, kuchepetsa kupuma utsi (ndi matenda a m'mapapo), kuchepetsa matenda a maso komanso kuchepetsa kupsa ndi moto.)*

		Chitetezo Mbaula	Rocket stove *(Mbaula ya loketi)*	Other, name type: _____ _____
2	Do you own an improved cookstove (*Inu muli ndi mbaula yamakono **[iyi]***)? (0=no, 1=yes, if no>>7)			
3	When did you acquire this improved cookstove (*Munaigula liti mbaula yamakonoyi)*? (mm, yy)			
4	How did you acquire this improved cookstove (*Mbaula imeneyi munaipeza bwanji)*?[4] (if not purchased>>5)			
5	How much did you pay for this improved cookstove? (*Munalipira ndalama zingati kugulira mbaulayi?)* (kwacha)			
6	If this improved cookstove were to break, how much would you be willing to pay to replace it *Mbaulayi itati iwonongeke, mungalole kuononga ndalama zingati kuti mugule ina)?* (kwacha)			

7	If not owned, why don't you own this improved cookstove (*N'chifukwa ninji inu mulibe mbaula yamakonoyi)*?[7] (rank in order, most important first, separated by commas)			
8	How much would you be willing to pay for each of these improved cookstoves (*Mungalole kulipira ndalama zingati kuti mugule mbaula iyi)*? (kwacha) (-999=unwilling to buy one)			

I will now ask you about the frequency of different stove-related health problems that members of your household experienced in the last 12 months (*Pano ndikufuna ndidziwe ngati anthu okhala pakhomo panu anakumanako ndi mavuto a zaumoyo obwera kamba ka mbaula yomwe mumagwiritsa ntchito mu miyezi khumi ndi iwiri (12) yapitayi komanso kuwirikiza kwa mavuto amenewa)*.

		PID	PID	PID	PID	PID	PID	PID	PID	PID	PID
9	In a typical day, is this person present in the same room as the stove while the fire is active (0= no, 1=yes, 2=cooking is done outdoors) *(Mu tsiku longa lililonse **[munthu uyu]** amakhalako mu chipinda chomwe mwaikamo mbaula yoti ikuyaka)*?										
10	Has this person had an illness with a cough at any time in the last six months? (*kodi **[munthu uyu]** anadwalako chifuwa mu miyezi isanu ndi umodzi yapitayi*) (0=no, 1=yes, if no>>13)										
11	When this person had the illness with the cough, did they breathe faster than usual, with short rapid breaths, or have difficulty breathing? *(Pa nthawi yomwe munthuyu amadwala, ankapumako mwabefu, mobanika kapena movutikira?* (0=no, 1=yes, if no>>14)										
12	Did their coughing illness affect this person's ability to work? *(Kodi nthenda yachifuwayi inamupangitsa munthuyu kuti asinthe magwiridwe ake antchito?* (0=no, 1=yes)										
13	Over the last six months, how many times has this person been burned by the stove, the hot pot, or the fire (*Mu miyezi isanu ndi umodzi yapitayi, **[munthu uyu]** wapsako ndi mbaula, poto otentha kapena ndi moto kangati)?*										
14	Over the last six months how many times did this person have an eye infection (*Mu miyezi isanu ndi umodzi yapitayi, ndikangati komwe **[munthu uyu]** anadwalako nthenda yamaso)*?										

	15	16		17		18		19	
	Enumerator: Enter the three most used (combine rainy and dry season) fuel sources from Section 12, Column 2	How much of (fuel type) does your HH use in an average week on your 3-stone stove? (-999=do not have this stove) *kodi mumaononga (zokolezera moto izi) zochuluka bwanji pa sabata, pa khomo panu, mukaphikira pa mafuwa?*		How much of (fuel type) does your HH use in an average week on your chitetezo mbaula? (-999=do not have this stove) *kodi mumaononga (zokolezera moto izi) zochuluka bwanji pa sabata, pa khomo panu, mukamaphikira mbaula ya chitetezo?*		How much of (fuel type) does your HH use in an average week on your rocket stove? (-999=do not have this stove) *kodi mumaononga (zokolezera moto izi) zochuluka bwanji pa sabata, pa khomo panu, mukamaphikira mbaula ya roketi?*		How much of (fuel type) does your HH use in an average week on your _____ stove (please specify stove type)? *Kodi mumaononga (zokolezera moto izi) zochuluka bwanji pa sabata, pa khomo panu, mukamaphikira mbaula ya_____? (nenani mtundu wa mbaula)*	
	Fuel Type Code[15]	Amount	Fuel Code Unit[6] from Section 12	Amount	Fuel Code Unit[6] from Section 12	Amount	Fuel Code Unit[6] from Section 12	Amount	Fuel Code Unit[6] from Section 12
Fuel Type 1									
Fuel Type 2									

E13: Social Capital

I will now ask you about the organizations and social networks that your household is part of (*Pano ndikufuna tichezeko nanu za mabungwe amene khomo lanuli limatengapo nawo mbali komanso maubale omwe muli nawo*).

E13.1: Organizations

1	2
Which household members are members of organization(s) and groups, including religious ones? *(Kodi ndi anthu ati a pakhomo panu ali mamembala a mabungwe)*? (PID)	Which organizations are they a member of *(**[munthu uyu]** ndi membala wa bungwe liti)*?[2] (please use one row for each organization)

E13.2: Social Network

	If you or another HH member asked, would it be easy or not easy to **[problem]** from **[person from your network]** ***(****Kodi ndichithu chophweka kwa inu kapena wina wanyumba mwanu ku* ***[chinthu]*** *kuchokera* ***[kwa munthu wa maubale anu])?*** (1=easy, 2=not easy)	First degree relatives of HH head or spouse (siblings, parents, sons, daughters, grandparents) *(Achibale apafupi akuchimuna kapena kuchikazi monga alongo kapena abale, makolo, ana, agogo)*	Other relatives of HH head or spouse (cousins, aunts, uncles) *(Achibale chapatali akuchimuna kapena kuchikazi monga atsibweni, msuweni, azakhali)*	Friends/ Neighbor, excluding village head (*Anzanu kapena anthu oyandikana nawo osawerengera amfumu)*	Village head (*Mfumu ya mudzi)*	Organization (*Bungwe)*
3	Borrow money for health expenses *(kubwereka ndalama zogwiritsa ntchito pa umoyo)*					
4	Borrow money for any event, such as a wedding or funeral					
5	Borrow money for food *(kubwereka ndalama zogwiritsa ntchito pa chakudya)*					
6	Borrow agricultural inputs (seeds, fertilizer, etc.) (*Kubwereka zipangizo zakumunda monga mbewu, feteleza)*					

E14: Credit Access *(Kapezedwe ka ngongole)*

I will now ask you about your household's access to credit. (*Pano ndikufuna ndicheze nanu zokhudzana ndi mene mumapezera ngongole)*

1	If you needed a loan for 25,000 kwacha, would you be able to obtain one from an **informal source** in the next two weeks (*Mutakhala kuti mukufuna kutenga ngongole ya 25,000 Kwacha, kuchokera kwamunthu mukhoza kuipeza masabata awiri akubwelawa?* (0=no, 1=yes)	
2	If you needed a loan for 25,000 kwacha, would you be able to obtain one from a **formal source** in the next two weeks (*Mutakhala kuti mukufuna kutenga ngongole ya 25,000 Kwacha kubanki ndi kumabungwe mukhoza kuipeza masabata awiri akubwelawa*? (0=no, 1=yes)	
3	If you needed a loan for 100,000 kwacha, would you be able to obtain one from an **informal source** in the next two weeks (*Mutakhala kuti mukufuna kutenga ngongole ya 100,000 Kwacha, kwina kulikokonse osati kubanki ndi kumabungwe mukhoza kuipeza masabata awiri akubwelawa*? (0=no, 1=yes)	
4	If you needed a loan for 100,000 kwacha, would you be able to obtain one from a **formal source** in the next two weeks (*Mutakhala kuti mukufuna kutenga ngongole ya 100,000 Kwacha kubanki ndi kumabungwe mukhoza kuipeza masabata awiri akubwelawa*?? (0=no, 1=yes)	

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M.Sc. Agricultural Sciences in the Tropics and Subtropics: Rural Development Economics **2010 - 2012**
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B.Sc. Business Administration: International Business **2005 - 2010**
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PUBLICATIONS

McNulty, E., Nielsen, T., & Zeller, M. (2016). Smallholder Farmers' Willingness to Invest in Irrigation Schemes in Dedza, Malawi. *American Journal of Rural Development*, *4*(2), 43-48.

Nielsen, T., Schünemann, F., McNulty, E., Zeller, M., Nkonya, E., Kato, E., ... & Mapemba, L. (2015). The food-energy-water security nexus: Definitions, policies, and methods in an application to Malawi and Mozambique. IFPRI Discussion Paper 01480, International Food Policy Research Institute, Washington, D.C.

McNulty, E. & Oparinde, A. (2015). Cassava value chain in Nigeria: A review of the literature to inform the integration of Vitamin A cassava. HarvestPlus Research for Action No. 4. Available at: http://www.harvestplus.org/node/598.

ORAL PRESENTATIONS AT CONFERENCES

Policy workshop and dissemination of results on IFPRI's "Virtuous Food-Energy-Water Security Nexus in Malawi". Presentation: "Preliminary Findings from First Survey Round". 4 November 2014, Lilongwe, Malawi.

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Clear oral and written communication in English (native) and Spanish (advanced)

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Horseback riding, soccer, skiing

_____ _____

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Author's Declaration

I hereby declare that this doctoral thesis is a result of my own work and that no other than the indicated aids have been used for its completion. All quotations and statements that have been used are indicated. Furthermore, I assure that the work has not been used, neither completely nor in parts, for achieving any other academic degree.

_____ _____

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