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**What Happens after Technology Adoption?
Gendered Aspects of Small-Scale Irrigation Technologies in
Ethiopia, Ghana, and Tanzania**

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ABSTRACT

A wide range of agricultural technologies are promoted to increase or stabilize yields and incomes, improve food security or nutrition, and even empower women. Yet a gender gap in adoption remains for many agricultural technologies, even for those that are promoted for women. This paper complements the gender and technology adoption literature by shifting attention to what happens after adoption of a technology. Understanding the expected benefits and costs of adoption from the perspective of women users can help explain the technology adoption rates that are observed and why technology adoption is often not sustained in the longer term. Drawing on qualitative data from Ethiopia, Ghana, and Tanzania, this paper develops a framework for examining the intrahousehold distribution of benefits from technology adoption, focusing on small-scale irrigation technologies. The framework contributes to the conceptual and empirical exploration of jointness in control over technology by men and women. It does this by identifying a series of decisions following technology adoption, and how these decisions affect how the technology is used, by whom, to whose benefit, and with what costs. Given the focus on technology adoption as a strategy for agricultural development and women's empowerment, understanding the intrahousehold distribution of costs and benefits and the jointness of control over a technology can help guide technology promotion in a way that advances programming objectives, rather than simply interpreting technology adoption as an end in and of itself.

Keywords: Irrigation, agricultural technology, technology adoption, gender

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1. INTRODUCTION

Given evidence that women's limited access to agricultural technology is an important factor constraining women's agricultural productivity (von Braun and Webb 1989; Quisumbing 1995; Peterman, Behrman, and Quisumbing 2010), increasing technology adoption among women farmers has emerged as a key strategy to close the gendered productivity gap in agriculture, promote women's empowerment, and advance broader welfare outcomes. By helping women farmers—particularly small-scale, resource-poor women farmers—produce more, add value, and use less energy, time, or natural resources, agricultural technologies can enable women to maximize the returns to their limited time, labor, land, and capital (Doss 2001).

Given these expected benefits, research has sought to understand what keeps women's observed rates of agricultural technology adoption low. The literature has shown that men and women have different preferences and face different types and severity of constraints to adopting technology (Doss 2001; Doss and Morris 2001; Ragasa et al. 2014). Technology adoption can be understood as three phases: awareness, tryout, and continued adoption of technology (Lambrecht 2014). Each phase presents particular challenges for women farmers. Awareness is limited by women's access to information and extension services to learn about the technology and how to use it (Doss et al. 2003; Ragasa et al. 2014). Tryout is limited by access to and control over land, water, labor, inputs, and other assets required to make use of the technology (Ani et al. 2004; Drechsel et al. 2006; Shiferaw, Kebede, and You 2008; Meinzen-Dick et al. 2011; Ragasa et al. 2014; Johnson et al. 2016); access to capital or credit to invest in the technology (Tiwari 2010; Regassa et al. 2014; Doss et al. 2003; Wickramasinghe 2009; White 1999; Olwande, Sikei, and Mathenge 2009); social learning and social capital to reduce perceived risks associated with adoption (Conley and Udry 2001; Hunecke et al. 2017); and appropriateness of design, including affordability, cultural acceptability, and suitability for women's specific agricultural tasks and physical requirements (Quisumbing and Pandolfelli 2009). Continued adoption is threatened by some of the same factors, as well as by appropriation of the technology or output of the technology by other

household members (e.g., von Braun and Webb 1989). Thus, many of the constraints that technology promises to alleviate are the same constraints that hamper adoption in the first place.

Notably, this literature focuses on constraints exogenous to the household and in the first two phases of technology adoption. However, such an approach reflects an assumption that removing constraints to awareness and tryout phases is sufficient for women to benefit from continued adoption of the technology in a way that is empowering.

As Lambrecht (2014) points out, during the continued adoption phase, also known as the trial phase (Lindner et al. 1982), farmers assess based on their own experience whether the returns from the technology relative to labor and input requirements are worth continuing use. These returns and costs, however, will likely not be the same for all household members, yet few studies examine who bears the costs or controls the benefits of a new technology. Although several studies document important changes in gender roles, including shifting the burden of labor and control over agricultural outputs, as a result of technology adoption (e.g., von Braun and Webb 1989; Doss 2001; Njuki et al. 2014), they do not unpack issues around use and ownership over the technology itself.

This paper complements the gender and technology adoption literature by shifting attention to what happens *after* technology adoption, in other words, during the phase of continued use. We examine evidence on the intrahousehold negotiations and roles in technology adoption gathered through qualitative fieldwork on small-scale irrigation technologies from Ethiopia, Ghana, and Tanzania.¹

Our focus is on small-scale irrigation technologies, particularly water-lifting technologies (e.g., rope and washer, motor, treadle, and solar pumps) that smallholders use on their farm plots and homestead gardens, exclusively or in conjunction with water-application technologies, such as drip systems, buckets, cans, or hoses. Despite the extensive use of small-scale irrigation, the value and extent remain underreported in official statistics (Woodhouse et al. 2017; de Fraiture and Giordano 2014). The current minimum pump irrigated area in Africa south of the Sahara is estimated at 340,134 hectares based

¹ The fieldwork for this study was undertaken within the project sites for the Feed the Future Innovation Lab for Small-Scale Irrigation and the Helen Keller International (HKI) Enhanced Homestead Food Production project in Tanzania.

on groundwater use (Siebert et al. 2010), but a separate study suggested the area is likely much larger, as smallholder farmers also widely use small pumps for lifting surface water (Merrey 2006). In some countries, smallholder irrigation area is estimated to be as high as large-scale irrigation schemes (Namara et al. 2014; Beekman, Veldwisch, and Bolding 2014), while the potential for further expansion may rival large-scale investment (You et al. 2010; Xie et al. 2014). The Comprehensive Africa Agriculture Development Programme under the New Partnership for Africa's Development is targeting 14.2 million hectares for small-scale irrigation development, which is about 7.5 times the area proposed for large-scale irrigation development (NEPAD 2009). Small-scale irrigation technologies are being promoted to potentially improve smallholders' dietary diversity, health, seasonal food security, and resilience to climate change and weather shocks (Domenech 2015).

Yet numerous studies have found that women are less likely than men to access both large-scale and small-scale irrigation infrastructure and technologies. In large-scale farmer-led irrigation schemes, implicit and explicit exclusion from scheme management decisions and irrigated land allocation limit women's access to water (Zwarteveen 1997; Meinzen-Dick and Zwartveen 1998; van Koppen 1998).

However, there has been relatively less attention to the gender aspects of small-scale irrigation technologies. The studies that have been done have focused on documenting the gender gap in adoption, mostly between male- and female-headed households, and the different kinds of technology men and women prefer (e.g., Upadhyay 2003). For example, a cross-country study in Ghana and Zambia found that small-scale technologies are adopted by female-headed households at two-thirds the rate of male-headed households, with female-headed households more likely to adopt manual technologies (e.g., buckets and wetlands) and male-headed households more likely to adopt motor pumps and river diversions (van Koppen, Hope, and Colenbrander 2012). Analyzing sales data from 2005 to 2013 from KickStart, a nongovernmental organization (NGO), Njuki et al. (2014) find that women made up only 6 percent in Tanzania and 18 percent in Kenya of all buyers of motor pumps distributed for sale by the NGO, and that these buyers were rarely women in married households purchasing pumps for their own use, but rather unmarried women or married women purchasing pumps on behalf of their husbands.

In studying households with both jointly and separately managed plots of land, these studies recognize that the household is not the appropriate unit of analysis (Doss 2001). Looking within the household, they examine several dynamics related to how men and women control and benefit from irrigation, including deciding what to grow on irrigated land, providing labor on irrigated plots, deciding whether to sell or consume irrigated produce, and controlling income from irrigated plots. Njuki et al. (2014) report men prefer to irrigate cash crops like tomatoes and women prefer to irrigate leafy vegetables that can be sold over a longer period of time, over which they could retain control over income; they also note that though women in pump-owning households have less say over production decisions, they can use the pump for their own managed plots. Both studies explore how technology adoption affects the whole household—not just the adopter or owner—in different ways.

Rather than taking technology adoption as a goal in and of itself, understanding the differentiated impacts of technology within the household can help orient technology promotion activities to advance specific development objectives. In this paper, we propose an analytical framework for analyzing intrahousehold dynamics—specifically considered as rights to small-scale irrigation technology. We then apply the framework to case studies using qualitative evidence of small-scale irrigation from Ghana, Ethiopia, and Tanzania.

Two bodies of literature inform our analysis. First, the literature on gender and assets highlights complexity in intrahousehold use, control, and ownership of resources (Johnson et al. 2016; Huyer 2016). Second, the property rights literature (e.g., Alchian and Demsetz 1972; Eggertsson 1990; Schlager and Ostrom 1992) provides concepts that help us further unpack the bundles of rights over assets (which can include technologies). By focusing on property rights as social relations among people (rather than as relations between people and things), this literature sheds light on the institutions that set and enforce rules over who can use resources in what ways. We have found that bringing together these two bodies of literature, extending the analysis of property rights as social relations to analyses within the household, provides new insights that are useful to our analysis.

The paper is organized as follows. Section 2 presents the analytical concepts and framework. Section 3 describes the methodology used to collect qualitative data in the three countries. Section 4 presents the evidence to illustrate these concepts, first discussing the awareness and tryout phases and then examining the intrahousehold distribution of rights during continued adoption. Section 5 discusses how this framework helps further our understanding of gendered aspects of technology adoption. Section 6 concludes with implications for technology adoption programs in general and insights for sustained adoption of small-scale irrigation technology in particular.

2. ANALYTICAL CONCEPTS AND FRAMEWORK

It is well established that members of households do not share the same preferences or pool their resources to improve overall welfare (Alderman et al. 1995; Doss 1996; Doss et al. 2014). But in rural settings where household members work together on multiple agricultural activities, some degree of joint use and decision making over assets is common. Meinzen-Dick et al. (2011) describe this idea in terms of a spectrum of jointness and separateness within the household.

Johnson et al. (2016) offer two possible definitions of jointness: (1) two or more individuals share rights to a single asset and make joint decisions or (2) individuals have different rights or different strength of rights over the same asset. In practice, they reflect that the second definition is more prevalent in developing-country agriculture: usually men have different, and stronger, rights than women. Following Doss et al. (2014), they focus on use, control, and ownership of assets. Women may have various use rights to an asset but often have more restricted rights to control how it is used, how the benefits generated by the asset are used, or when and where to buy or sell an asset (i.e., alienation rights, which are usually considered key in defining ownership).

Rights to the asset itself may not be sufficient if they do not extend to control over the income derived from use of the asset. For example, Quisumbing et al. (2013) found that, even though the value of assets that were reported as jointly owned increased as the result of a dairy value-chain intervention, control of dairy outputs remained segregated by gender; while women controlled decisions regarding the use of milk for home consumption, men controlled all decisions related to financial transactions, including revenues from milk sales, whether to sell milk, and whether to buy or sell cows. At the same time, they noted that if women sell the milk, they can control the income, as long as the revenues do not surpass a certain threshold (Quisumbing et al. 2013).

Similarly, in their research on *flypaper effects* (examining whether targeted asset transfers for women “stick” to women) of an asset-transfer program targeting the ultra-poor in Bangladesh, Roy et al. (2015) found that, at least in the short term, women are able to retain control over an asset transferred to

them even if it is not traditionally a woman's asset. However, women's control over the asset did not extend into control over the income generated by the asset, which was predominantly used by men for investments of their choosing.

As described above, Njuki et al. (2014) point out that women can benefit from a technology or asset even if they do not have recognized ownership. In a case study in Tanzania, men represented the majority of adopters of irrigation pumps distributed through a gender-blind, market-based approach, yet women still were able to use the pump and influence decisions on how it was used, including whether to irrigate the crops grown on plots they manage. However, this study again found that revenue from the sale of those crops tended to be controlled by men.

General terms of ownership and control can describe a range of possible intrahousehold dynamics with respect to an asset—comparing simple ownership of assets across contexts rarely provides opportunity to compare like with like. To assess the implications of different rights, including the benefits and costs conferred to different people within the household, these different rights need to be identified.

The social science literature on property rights can help to elucidate these issues. While *rights* may seem too strong a word for many of the arrangements governing intrahousehold use and control of technologies, a particular strength of the property rights literature is its focus on property rights as social relations backed by particular institutions. Yet while the property rights literature has focused on state, community, and religious institutions, it has not looked deeply into households as institutions that shape property rights. In much the same way that communities use collective resources, households can also be viewed as an institution that recognizes and enforces property rights (Doss and Meinzen-Dick 2015). These are de facto rights, determined by the social norms influenced by an historical, institutional, and legal context, but usually enforced by other household members.

In particular, the concept of *bundles of rights* allows us to identify how different actors can claim different types of rights over a resource or asset. Although it is possible to identify many different individual rights, there are two major ways of classifying bundles of rights.

Schlager and Ostrom (1992:250–251) refer to a hierarchy of five bundles of rights, which they apply to natural resources (such as land or fisheries):

- **Access:** The right to enter the physical space of the resource (e.g., walk through the forest)
- **Withdrawal:** The right to take the products of a resource (e.g., catch fish, remove water)
- **Management:** The right to regulate use and modify or transform the resource
- **Exclusion:** The right to determine who can use the resource
- **Alienation:** The right to lease, sell, or transfer either the management or exclusion rights associated with the resource, or both.

The first two of these are generally considered *use* rights, while the latter three are *control* or *decision-making* rights. *Ownership* is generally considered to be having all of these rights, including alienation. This classification has proved very useful for analysis of many aspects of land and natural resource management. In synthesizing the results of eight agricultural development projects on women's empowerment, Johnson et al. (2016) focus on three key bundles: use, control (which includes decision-making rights of management and exclusion), and ownership, which includes all bundles of rights. But as useful as this classification is, it misses one aspect that is of fundamental importance for intrahousehold control over agricultural technologies: the control of the income (or other benefits) generated by the technology.

An alternative way of identifying bundles of rights derives from ancient Roman law and is reflected in most civil law systems today, capturing this control over income in the *fructus* concept (see Benjaminsen and Ba 2009, 77):

- **Usus:** The right to use
- **Fructus:** The right to the products, increase, or profits of the resource
- **Abusus:** The right to encumber or dispose of property through donation, sale, destruction.

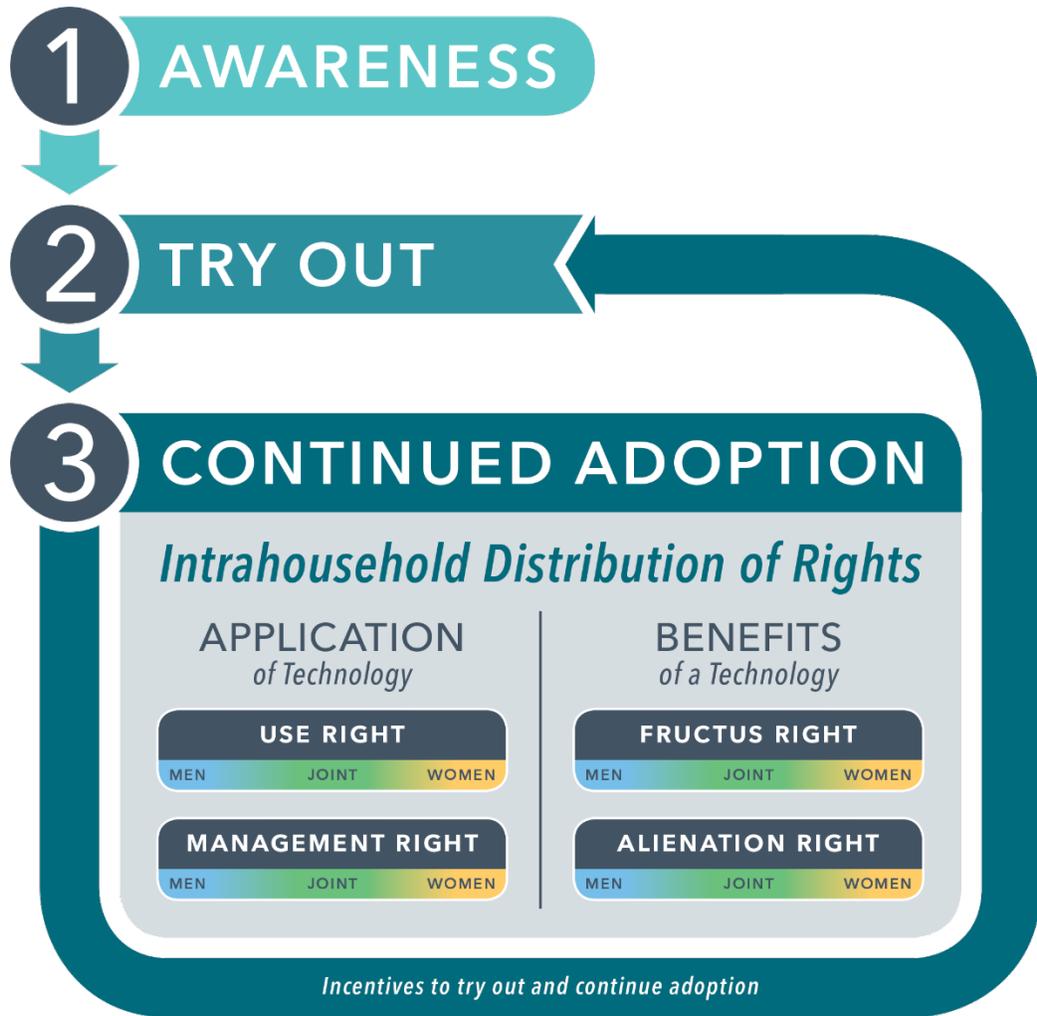
While *usus* covers the use rights of access and withdrawal from the Schlager and Ostrom framework, and *abusus* corresponds well with alienation, the management/exclusion rights in the Schlager and Ostrom framework are missing from the Roman classification, and the *fructus* rights from civil law are missing from the Schlager and Ostrom classification. Each of these rights can be important in particular contexts for analyzing intrahousehold relations with regard to technologies. But we find it useful to think about the following bundles of rights: use, management, *fructus*,² and alienation. In the case of irrigation technology, use and management refer to rights over the application of the technology, whereas *fructus* and alienation refer to the rights to the benefits of the technology.

Building on the bundle of rights concept, we first examine gendered factors that influence awareness and tryout of a technology, and then look at the particular use, management, *fructus*, and alienation rights that are claimed and operationalized by men and women in the household. This framework shows how the adoption of technology can carry differentiated costs and benefits for people within the household.

Just as various institutions at different scales influence the rules of resource use, different institutions affect intrahousehold resource allocation and the control over technologies. A right that is recognized across multiple institutions tends to increase the strength of the right; conversely, it is more challenging to claim a right to an asset that is not backed up by institutions beyond the household level. Analyzing technologies in this way can not only show how the benefits and costs of a technology are distributed across different members of the household, but also how different members can perceive different costs and benefits, which influences their preferences for and willingness to try out and continue use of technologies, as illustrated in Figure 2.1.

² Although *usus* and *abusus* adequately translate in our framework to use and alienation, we have chosen to preserve the term *fructus* in our framework in the absence of a precise and appropriate English nomenclature that captures the meaning of the right to have profit or loss of income or products.

Figure 2.1 Gender in the three phases of technology adoption



Source: Authors

3. METHODOLOGY

This study draws on qualitative data collected in 19 communities in Ethiopia, Ghana, and Tanzania in 2016. In total, we conducted 38 gender-separated focus group discussions with 375 men and women. The fieldwork took place in small-scale irrigation pilot sites of the Feed the Future Innovation Lab for Small Scale Irrigation (ILSSI)³ in Ethiopia, Ghana, and Tanzania and the Helen Keller International (HKI) Enhanced Homestead Food Production project in Tanzania.⁴

The sites for the ILSSI pilot studies were chosen based on access to an adequate source of water for dry-season irrigation, proximity to an output (produce) market, some experience with manual irrigation (bucket based), and interest of the community to participate in a pilot using their own land, labor, and other inputs. ILSSI pilot sites tested petrol-fueled motorized pumps, photovoltaic solar pumps, and manual water-lifting technologies (e.g., rope and washer or pulley) in combination with various field-application technologies (e.g., drip or furrow) and irrigation-scheduling tools for around 200 farmers. The project distributed solar-pump and manual-lifting technologies to individual farmers, while motor pumps went to a few small groups of farmers. Farmers committed to paying for the technologies over the period of the field intervention.

The HKI project follows a model of Village Model Farms and Farmer Field Schools that target women for training on homestead food production and nutrition. In the Ukerewe and Sengerema districts in the Mwanza region of Tanzania, IFPRI linked a local NGO, Sustainable Environment Management Action (SEMA), with HKI, through HKI's project Creating Homestead Agriculture for Nutrition and Gender Equity (CHANGE). The CHANGE project aimed to improve the nutritional status of infants and young children and their mothers through interventions targeted to women to enhance homestead food production and induce nutrition behavior change. Through the collaboration with SEMA, drip kits were integrated into the CHANGE project. Specifically, SEMA distributed 78 drip kits to CHANGE beneficiary farmers (all women) and provided technical assistance on drip kit installation, use, and maintenance to

³ <http://ilssi.tamu.edu/>

⁴ <http://www.hki.org/our-work/improving-nutrition/helping-families-grow-better-food#.WPEjIYWcGwA>

resource farmers and other community members. The fieldwork included control sites in the same district, with comparable agroecological conditions and livelihoods, but where no small-scale irrigation activities were being promoted.

We applied a focus group protocol consistently across all sites involving separate group discussions with women and men farmers. Participants were recruited in consultation with key informants in the villages studied, following selection criteria that included a combination of irrigators and nonirrigators or rainfed producers, women and men, field intervention participants and nonparticipants, and age groups.

The discussion questions for focus groups examined gender preferences for water technologies, technology choices as aligned to existing community and household needs, roles and responsibilities of both men and women, household use and management of water with different technologies, and perceived benefits and incentives related to small-scale irrigation technology adoption. The number of participants in each focus group discussion ranged from 6 to 16 (Table 3.1). Discussions took place in Swahili in Tanzania, in Amharic in Ethiopia, and in Gurunsi and Dagbani in Ghana. The discussions lasted about 2 hours and were held in primary schools or neutral community settings with visual and audio privacy. A team of national facilitators in each country was trained by the authors to conduct focus group discussions using this protocol. Male facilitators led the male discussions, and female facilitators led the female discussions, with notetakers assisting them and recording the meetings. Afterward, recordings were transcribed and translated into English. Responses and comments from each focus group were then organized into spreadsheets following the modules to enable cross-group and -country comparison.

Table 3.1 Location and number of participants in focus group discussions

Site	Region	Men	Women	Project
Ghana				
Zanlerigu	Upper East	6	9	ILSSI
Nyangua	Upper East	12	5	Control
Dimbisinia	Upper East	11	6	ILSSI
Bihinayili	Northern	16	15	ILSSI
Ethiopia				
Robit Bata	Amhara	13	13	ILSSI
Dangila	Amhara	11	9	ILSSI
Upper Gana, Jawe (Lemo)	Southern Nations, Nationalities, and Peoples' (SNNP)	9	12	ILSSI
Tanzania				
Rudewa Mbuyuni, Kilosa District	Morogoro	10	9	ILSSI
Sangasanga, Kilosa District	Morogoro	9	11	Control
Mkindo, Mvomero District	Morogoro	9	9	ILSSI
Kondoa, Mvomero District	Morogoro	10	10	Control
Mawemairo, Babati District	Manyara	8	10	ILSSI
Mapea, Babati District	Manyara	9	9	Control
Nyampande, Sengerema District	Mwanza	8	10	HKI
Nyamazugo, Sengerema District	Mwanza	8	10	HKI
Chifumfu, Sengerema District	Mwanza	9	12	HKI
Nyamatongo, Sengerema District	Mwanza	9	11	HKI
Muriti, Ukerewe District	Mwanza	9	11	HKI
Kazilankanda, Ukerewe District	Mwanza	9	9	HKI

Source: Authors

In addition to the focus group discussions, data from individual interviews with 79 irrigating farmers (38 men and 41 women) in Upper Gana and Jawe and Bale (Oromia Region) were added to the spreadsheets.⁵ Those interviews were conducted under the Africa RISING project in Ethiopia, based on similar modules and questionnaires. The farmers had been provided the same set of technologies following the same protocol as those in the Innovation Lab project.

⁵ <https://africa-rising.net/tag/feed-the-future/>

4. RESULTS

Interviews with men and women from 19 communities in Ethiopia, Ghana, and Tanzania reveal several broad patterns in intrahousehold rights over irrigation technologies after the technology is first adopted. The data from the three countries show that the costs and benefits of technology adoption are not equally distributed across the household. One member of the household generally does not exclusively hold rights of use, management, fructus, and alienation, but men are more likely to hold more of these rights as well as stronger claims to these rights. Use and management rights, while more commonly measured by technology-promotion projects, do not guarantee fructus or alienation rights. In this section, we first discuss findings on the gendered constraints in the first two phases of technology adoption, awareness and tryout, and then we examine use, management, fructus, and alienation rights over small-scale irrigation technology.

Awareness and Tryout of Technology

The technology adoption literature tends to underrecognize intrahousehold negotiation and the role of women in adoption decisions (Magnan et al. 2014), yet our findings reflect that gender affects both awareness and ability to decide to try out a technology. Although our data show that women face additional constraints to awareness and tryout due to intrahousehold relationships, women do play an active role in bringing new practices and information into the household.

With respect to the awareness phase, respondents in Ethiopia explain that women are less aware of technologies because they are unable to attend informational meetings. In addition to domestic work that prevents their attendance, some women say husbands do not inform them of meetings (Nigussie et al. 2017).

In Tanzania, particularly in communities where HKI was working, both women and men note that women are targeted to participate in groups and are therefore seen as the first to receive new information and training, which they then bring back to the household. Despite this approach, many women describe needing permission from their husbands and being “afraid” of participating in groups without consent of

men.⁶ Men describe how some groups “come targeting mothers, but all the details must be given to the dad first” (Mapea, Tanzania) and say that groups have failed when they did not inform or include men.

Men remain the gatekeepers to women’s participation and use of time. A man in Nyamatongo says he can stop his wife from joining a group “if the group has no benefits to me.... Most of times when they want to join the group, they must consult men. For example, my wife consulted me about BRAC, which I stopped her from joining.” Explaining why they may block women’s participation, men cite concerns about household tasks going uncompleted, a shift in the balance of power between spouses (men in Kondo, Tanzania, say “Your marriage is at stake because your wife has become overconfident”), and women coming out of groups “with a static mind...since that’s how she was taught on the project” (Muriti, Tanzania).

Some men do acknowledge that women can bring benefits to the household through their participation: “The education she gets from it she will keep, and whenever opportunity comes for a machine or starting a horticulture project, she will do it with determination.... When you look at yourself as household head who can do everything, you will block others' fortune.” (Nyampande, Tanzania). Women acknowledge that even if they are allowed to participate in a group, “the family plot has to be top priority” over group activities (Nyampande, Tanzania).

Women also explain that men’s control over women’s access to land influences their ability to try out new technologies and practices learned in their training. Women in Nyampande say men can lease out land without their knowledge, reducing their security of tenure and limiting their access to land (“He will just inform you that I have lent a land to so and so, therefore this time you will deal with the certain piece only”). When they want to try out what they learned in the group, they need to convince their husbands to allocate them a parcel, because “man is conventionally the owner of the plot.” Women say land rental is a potential option for women with financial resources, but if they try to rent independently from their

⁶ In our study, group-based approaches are particularly used in HKI projects, so are best represented in the Tanzanian study sites.

husbands, “he may overhear that you have rented a plot without his knowledge; then he will tell you, you were bribed by a man” (Nyampande, Tanzania).

In terms of deciding to try out a new technology, most respondents, women and men, report at first that the household makes joint decisions. However, men seem to be able to decide without consulting women or have the final say when there is consultation, whereas women can only adopt technology with men’s consent. Women can propose the idea but need to persuade their husbands to accept: “It will be upon me to keep on convincing him to put it to use” (Nyampande, Tanzania). In Rudewa Mbuyuni, Tanzania, men explained that “wives must get permission from [their] husband to irrigate. [The husband] may refuse for personal reasons or because he doesn’t know what is going on—he needs to be informed.” Men said in Robit Bata, Ethiopia, that they would have already decided before discussing, particularly noting that “sometimes some of the things are understood by men, while they are not understood by women.” Yet in both Ethiopia (Lemo) and Ghana (Dimbisinia), men said women want to adopt technologies more than men.

A woman’s ability to try out technology or agricultural practices appears stronger when she can apply them on plots of land under her control, and when the technology or practice has lower resource requirements in terms of capital, land, time, and water. Although women’s group production can increase control over land and reduce these resource requirements per person, men largely control women’s involvement and even awareness of these group opportunities in the first place.

Use Rights

Use rights are the most likely of the rights to be held jointly. However, while use is generally recognized as a right in the property-rights literature and encouraged through the promotion of “women-friendly technologies,”⁷ use is also an obligation that carries costs in time and energy. Consistent with findings from earlier work (van Koppen, Hope, Colenbrander 2012; Njuki et al. 2014), women often have the right to use manual, labor-intensive irrigation technologies, such as buckets and watering cans, while men

⁷ <http://www.ata.gov.et/programs/sustainable-inclusive-growth/irrigation-drainage/>

operate mechanized irrigation technologies, such as motorized pumps. While there was no outright opposition expressed to women's use of pumps, men provide various rationalizations for why women do not typically use pumps, including excessive technological complexity, physical requirements to operate, and difficulty hiring laborers. In part because of the labor requirements and costs of fuel, the use of pumps is considered worthwhile for higher market value crops⁸ but not for subsistence agriculture, and since women tend to cultivate separate plots that are less market oriented, men say it is rare to see women using pumps; "rather they can grow simple vegetables for subsistence" (Kondoa, Tanzania). Water requirements of men's and women's crops were also given as an explanation for why women should use manual lifting and application technologies. Pumps are considered more suitable for crops that men manage (tomatoes and onions), which can be flooded, whereas respondents said the leafy greens managed by women require regular water application in smaller quantities, making them more suitable for watering cans, buckets, or drip irrigation.

In some communities, women help their husbands irrigate with pumps, as men note, "You can't do it alone" (Nyampande, Tanzania). In Ethiopia, women carry pumps to plots for their husbands to operate. Women are less likely to prefer diesel pump technologies because carrying the pumps and related pipes adds to their labor burden. Rather, women are more likely to prefer solar technologies fixed near the household, which reduces the labor burden for obtaining water for domestic purposes and for irrigating vegetables (Nigussie et al 2017). Men do not want women's agricultural labor to compromise domestic responsibilities, lest they "delay receiving *ugali*" (Mapea, Tanzania) but still expect women to manage all domestic work while contributing equally in agricultural labor:

"[Agricultural] responsibilities are for both of us, husband and wife.... So even if it is to work in the irrigation field, my wife can still assist; if it is uprooting the trees, my wife can still help to collect them. The only activities which we differ are household chores, whereby when we reach home, she is the

⁸ As with gardens vs. horticulture, the concept of "high-value" crops tends to refer to market value and does not consider the food security or nutritional value of home consumption.

one cooking as I am resting. But in agricultural activities, the ratio is 50–50.” (men in Rudewa Mbuyuni, Tanzania)

Women express concern about the time burden of irrigation and agriculture for their own well-being, their children’s development, and their marriage, and note that the burden does not end when they rest for the day:

“[The marriage] has to break because the whole day you were in the farm working, and it’s very far. In the evening you have to do home chores, including attending to younger kids. And at night you have to do another work—it’s really disgusting; first of all, there is no marriage, it’s raping.”

Asked how the community perceives women who irrigate, women say those who use manual technologies are seen as “suffering” (Mkindo, Tanzania). Compounding the time burden is the fact that many of the irrigated fields are far from the home, requiring long travel time and sometimes even sleeping over at the field to guard against theft or prepare to receive water from the canal. Women also expressed frustration with drip irrigation in some of the HKI sites, since filling the tank that is connected to the drip line with water still requires heavy manual labor with buckets.

Despite these norms around use rights of pumps, women in Ghana and Tanzania expressed their desire to obtain motorized pumps, suggesting they see these roles as negotiable. In Mapea, Tanzania, a woman proposed they should get “machines for pulling water...rather than the punishment we get through irrigating by buckets; it delays the easiness of life. But if you get the machine, even a woman can do the work and get back home; hence it is good for the community.” In Dimbisia, Ghana, the introduction of motor pumps saved women time in fetching water, which led to further changes in gender roles in agriculture: Men prepare the beds for both women’s and men’s plots, women nurse seedlings, and women do the marketing. Men in the Upper East Region sites in Ghana also expressed an incentive to support women to adopt irrigation technologies—preventing their wives from out-migrating during the dry season, which they say leaves men with all household domestic work.

Management Rights

While the distribution of use rights tends to reflect the gendered division of household labor between domestic and productive responsibilities, the management right corresponds to the gendered division of agricultural labor. In a context where household members manage both joint and individual plots, there are potentially competing applications for one household irrigation technology that can be shared.

Therefore, the management right—where, when, and how the technology is used—has implications for crop choice on these separate plots, yields, and income generated by the different plot managers.

Throughout the discussions, men were described as the “pioneer,” “supervisor,” “manager,” or “leader,” while women are considered the “helper” for agricultural production activities, to “lead her army after my orders.” Our findings reflect that men typically control management rights, applying mechanized technologies to plots they control; women’s plots are not prioritized for irrigation, and only in a few instances in Ghana, men operated household pumps on both men’s and women’s plots, with women noting these wives were “lucky,” suggesting it is neither common practice nor expected.

Because of women’s dependence on men for access to land in these three countries, they have to accept the land they are allocated, which may or may not be suitable for irrigation or close to a water source. Women’s land access can have a seasonal dimension. In Ghana, women have access to more land in the dry season through plots that are not being used as men engage in other economic activities, like fishing. In Nyangua, Ghana, women explained that because dry season irrigation is done on borrowed or rented plots, as opposed to inherited land, women have more control over cultivation decisions, including irrigation. Women in multiple sites stated a preference for irrigating land that is closer to home to reduce time burden and protect their produce against theft, but their limited influence in the allocation of land constrains their management rights to household technology.

The characteristics of the technology influence the distribution of management rights. Technologies that can be moved, like motorized pumps or hoses, can be more easily shared on different plots than a rope and washer or drip irrigation system. In Dimbisinia, Ghana, because it is men’s responsibility to dig the wells each dry season, men explain that they control the use of the water from

those wells, including water-lifting pumps. In Lemo, Ethiopia, solar pumps and rope and washer water-lifting technologies are installed near the homestead, which enables women to use the water for both domestic purposes and irrigation. This gives women marginally more control over rainy and dry season management of those technologies than mobile technologies, such as motor pumps (Nigussie et al. 2017).

Fructus Rights

Fructus rights are less commonly measured as a project outcome compared with the previous two rights, perhaps because of persistent assumptions that households pool resources or that what happens within households is beyond projects' control or ability to monitor. However, our findings show that projects can change how they affect fructus rights, and despite the emphasis on use and management rights, neither right guarantees fructus rights over the outputs of irrigation technology for women.⁹ Our findings show that household members may have stronger or weaker fructus rights, as indicated by who (1) decides whether to sell produce (vs. consume, store, etc.), (2) decides when and where to sell the produce, (3) sells the produce, and (4) receives revenues from sale. These different decisions affect knowledge of revenues and subsequent bargaining power over their use.

In Tanzania, women in nearly every community mentioned that it is common for men and women to collaborate throughout the season with both their labor and planning in irrigated agricultural production, but when the time comes to sell, men sell away from the farm gate, without women's knowledge or consultation about the quantity, timing, or price of sale. Men therefore have a greater fructus right over this income, and women's lack of knowledge leaves little basis for negotiation: "What you harvest is his.... That is the truth" (Nyamazugo, Tanzania). A woman in Mawemairo explains:

In most cases, men involve us in decision making, but during harvesting, you are left behind. I don't know how others see it.... During cultivation, there is love at home, good talks like, "This year after we harvest, we will make this and that, and we will take our child to there and do this for him." You use

⁹ The outputs of a technology include irrigated crops (e.g., tomatoes, onions, and vegetables), byproducts (e.g., crop residues for fodder and wild herbs), and income generated by the technology (e.g., revenue from selling crops, renting out a pump, or even charging mobile phone batteries using the photovoltaic panels on a solar pump).

all your energy, and when harvesting time comes, after taking the sacks in the warehouse, and you touch him, then conflict will rise in the house, and he will tell you, “With the little income we have, do you think we can manage big things as those?” Then you keep quiet.

Fructus rights are strengthened by withholding information from a competing spouse—by both spouses. Despite women’s labor in agriculture, “when it comes to selling, it’s a husband who does it, and thereafter he will just inform you about the sales and put all the money in his pocket” (Nyampande, Tanzania). Women say the husband “signs the sacks at the warehouse and sells, but you won’t even know of the amounts, whether he gives you a fake calculation. You just have to accept.” Women in three communities in Tanzania (Mapea, Nyampande, and Mawemairo) discuss how men store the paddy harvest at a warehouse next to the mill:

But as days goes by, you can’t go daily to check them [the sacks], since you aren’t the one who signed for it inside there, because his fellow men will think of me oppositely, so I just remain at home. If you will need rice and tell him, then he will look how many kilograms can cater for this family, but he doesn’t bring. When you remind him again, he will tell you, “stop disturbing” while he goes to the machinery store and grinds paddy but doesn’t tell you. After some days if you tell him, “I would like to get a new *kitenge*,” he will ask you, “Where is the money?” While he has already sold it and it’s over. The next season comes, and you all go to the farm again (Mapea, Tanzania).

A woman in Mawemairo describes how her husband stores the full paddy harvest at the warehouse and “sells without notifying you. While you are thinking it’s 100 sacks of paddy [at the warehouse], he has already sold some of it, and when you go to check, only 40 sacks of paddy are left behind. The rest you don’t know where they went, and if you ask, it’s a conflict inside the house.” Men mention separately that they do not need to share this information: “A man can sell and say nothing.”

Women in Mawemairo explain that income from irrigated paddy does help them “build good houses,” but they point out that they do not have a say over how this income is spent: “He only cares you are living in a good house, you have a TV and good utensils. Then he expects you to be satisfied”

(Mawemairo, Tanzania). In Mapea community, a woman explained, “If you tell him [what to do with the income], he asks you, ‘Did you come with it from your home?’”¹⁰

Women hold fructus rights over certain crops and income levels, but above certain revenue thresholds become obligated to share fructus rights, giving money to their husbands. In several communities, women explained that they retain control over income if revenues are low: “Men regard vegetable gardening as a low income generating activity compared to tomatoes even if the processes are the same”¹¹ (Nyamazugo, Tanzania). In Nyamatongo, a woman explains that the sale of vegetables is “your money and he doesn’t ask you.” Because men’s “eyes are onto high-income activities that generate money in a lump sum, that is why they are not so much into vegetables, though they can still borrow money from you” (Nyampande, Tanzania). Although men cannot control their income, in this same community, women note that men now “can even ask for 1,000 shillings, and you can’t deny him because he knows you have money.” The distribution of fructus rights likely presents a disincentive for women to try to earn larger sums of money, and it may also encourage women to grow crops that can be harvested continually in smaller amounts and sold by women themselves.

Women across sites value the greater independence and respect gained from income generation. Women appreciate not having to ask their husbands for household needs and food. In Robit, Ethiopia, women said, “We do not expect money from men’s hand; there will be no problem for [women to pay for] home expenses” because “generating incomes avoids dependency on men.” Women in Nyamatongo, Tanzania note: “It has changed due to gardens.... It’s different because I don’t depend on a man, since I sell the veggies and get money and buy exercise books, buy soaps and clothes.”

In the Ghana sites, women play an active role in taking produce to markets and negotiating prices. Both women and men see irrigation as enabling women to obtain their own income and be less reliant on men. Women expressed satisfaction that after adopting irrigation practices, they were able to pay school

¹⁰ Meaning, did the woman bring it from her natal home; women may have stronger claims on assets brought to marriage (see Quisumbing and Maluccio 2003 for further analysis of the empowerment effects of assets brought to marriage).

¹¹ This distinction between referring to women growing vegetables as “gardening” versus growing tomatoes (which are a vegetable but presumably a monocrop) mirrors the development discourse that often refers to the former as “kitchen gardens” and the latter as “horticulture.”

fees and medical costs for their children without relying on their husbands, as well as purchase small items for themselves, such as new shoes. In Bihinayili, Ghana, women said: “Our husbands cannot tell us how to spend our income.” As noted above, in one site, men particularly supported women’s irrigation on the women’s plots to increase their wives’ cash income because this meant the women were less likely to migrate to neighboring areas to work as hired farm labor.

Women’s fructus rights may also be limited to the types of purchases they can make. In Lemo, Ethiopia, women’s fructus right only extends to using the income from irrigated farming on food and small household purchases, but in Robit, Ethiopia, women bought clothes with the income earned from irrigating vegetables near the household using manual water-lifting technologies, following the “rule” that women tend only to be allowed relatively small household purchases and food.

Nonfinancial benefits related to social status were noted in some cases. Women in Zanlerigu, Ethiopia, said that irrigated farming (with watering cans) had increased their income, and as their individual income increased, so did their joint decision making with their spouse; other women in Dimbisinia, Ethiopia, said that irrigated farming “makes people appreciate you... gives you a sense of belonging.”

Alienation Rights

Alienation rights refer to the right to transfer by sale, lease, gift, or inheritance. In our findings, there were no instances of alienation of irrigation technology itself, as there is not much of a secondary market for the equipment. However, patterns of alienation rights over other assets indicate that they are predominantly held by men. In Nyamazugo, Tanzania, men say it is common to give woman a plot of land and take it away from her at the husband’s discretion, and she cannot voice concern as long as men fulfill their roles by bringing home meat for the family. Women in Nyampande similarly reflect that husbands can lease out a piece of land, which women may have been using, and only inform them afterward. Women in this community also comment that even over small assets like poultry, they do not have alienation rights: “You know they are talking of gender equality, but in reality, it does not exist. At

times, you may have to ask for permission to slaughter chicken for visitors; otherwise, if you force doing it, you will have to pay for it later.”

In Ghana, pumps are major assets, as valuable as cows, and therefore, considered men’s property within the household. In Nyangua, women said regardless of whose money is used to buy cattle, it still belongs to the husband. Likewise, in Zanlerigu, women discussed pumps as assets similar to cattle; women can “own” animals, but they are regarded as men's assets and a woman needs her husband's permission to buy or sell animals. Women say that even if they are given a pump by a project or purchase one on their own, men are the owner of the pump in the household.

5. DISCUSSION

Despite the challenges of time burden and energy expenditure, women value irrigation, particularly on crops where they control the management and fructus rights. However, in our study sites, these are commonly small-scale horticulture plots with labor-intensive irrigation methods. On plots where women hold greater management and fructus rights, they also shoulder both the right and burden of labor to provide irrigation, mostly without help from husbands or hired labor. This is often after prioritizing their labor for family plots, where they hold weaker rights, and domestic responsibilities. The resulting time constraints appear to limit women's ability to negotiate greater use and management rights to technology, with men concerned about women's ability to fulfill duties to the family plot and domestic chores if they take on greater rights to a technology. Use and management rights, while not a guarantee of fructus or alienation rights, do seem to strengthen those claims, as women indicate the feeling of being cheated by their husbands when they sell paddy produced through family labor without their knowledge. However, none of the women cited examples of successfully negotiating for fructus rights. They are largely inhibited by information asymmetry regarding the sale of irrigated agricultural production and a desire for household harmony.

Women and men in many cases acknowledge the benefits of sharing some rights in a collaborative household. For the use right, this is largely out of necessity: "We all collaborate because if you do not have a machine, that is the only way to go" (Kondoa, Tanzania, women). However, men also acknowledge that allowing women's input into decision making reduces men's vulnerability. Men identify the responsibilities associated with their own gender role and point out the risks if they fail in these responsibilities: "Man is head of household and woman is adviser.... but even leaders can be despised if you are useless. Women and children in the household respect you if you are successful" (Sangasanga, Tanzania). Saying the "patriarchal system is almost over," another man in Sangasanga, Tanzania says, "When you act as if you are the sole decision maker, all your plans fail, so if that fellow doesn't do that work with one heart, you will fail. Anything can happen, maybe sickness, or you may

travel and when you leave, all your plants will die. She must agree to the decisions.... They say unity is power.”

The focus group results do suggest that the distribution of these rights not only changes by context but shifts over time as incentives change. In particular, mechanized irrigation is a new phenomenon in these countries, and gendered rights to these technologies are contextually specific and still evolving. Intrahousehold relationships may strongly influence the rights to technologies, but the introduction of new technologies can also reshape the distribution of the rights. In Tanzania, men recognize how agricultural gender roles have changed after broad adoption of drip irrigation and horticultural training: “In the past women did not practice horticulture. They used to see it as a men's business, and some of the crops were regarded as women's crops, for example green grams and beans. When we [men] realized it is beneficial [to involve women in horticultural crop production], we started to venture with them” (Nyampande men). In Ghana, women felt their power within the household grew as their income and social status increased with irrigated production. Men also started to encourage women to adopt irrigation technologies (albeit manual) in an effort to increase women's income and prevent them from migrating to cities or large commercial farms for work. In other cases, both women and men recognized how women's access to technology freed time for other uses and benefited household food security. Promoting greater appreciation for women's contributions to the household seemed to lead to increased willingness to make joint decisions.

6. CONCLUDING REMARKS

Most gender and technology adoption research to date has focused on gendered constraints to acquiring technology—in other words, during the awareness and try out phases of technology adoption (Lambrecht 2014). This has led to an emphasis on constraints exogenous to the household that prevent women from learning about or trying out a technology, while considerably less attention has been paid to the gendered impacts of a technology once a household starts using it. Assumptions that technology adoption either benefits the entire household equally, or, conversely, only benefits the “adopter” of the technology, have obscured the intrahousehold costs and benefits associated with a new technology.

Applying an adapted bundle of rights framework to technology within the institution of the household allows us to draw new attention to the gendered impacts of smallholder technology adoption. These impacts in turn have implications for future technology adoption and for development. The distribution of rights to a technology shape whether technology adoption is sustained or disadopted, and the anticipated distribution is likely to influence men and women’s interest in trying out a technology. Furthermore, the intrahousehold distribution of rights provides a useful framework for investigating how a technology is used, for what kinds of outputs, who bears the labor costs, and how the outputs themselves are used. Understanding these dynamics can shed insights on why certain development outcomes are or are not achieved.

Projects that promote irrigation technology for women should be aware that rights to technology can be subject to a form of “elite capture” within the institution of the household. In the absence of complementary institutional or social change, targeting women with irrigation technology alone is unlikely to confer full rights over the technology to women, since the rules of the household often override any project-level rules and expectations. Furthermore, interventions should not conflate use and fructus rights, as they may inadvertently increase the labor burden for women without substantively improving rights to the benefits generated by the technology, such as control over the income from irrigated produce.

The distribution of rights to irrigation technology is closely related to gendered land rights and division of labor. Just as women are not allocated land beyond what is required for subsistence production (Lambrecht 2016), women rarely apply mechanized irrigation technologies to the plots of land they primarily manage because the low commercial value of women's production is not seen to justify the cost of application. Rather, women in male-headed households are considered helpers in the use of mechanized irrigation on men's plots. While they have use rights in some cases to operate a technology, they prioritize their labor on their husband or family's plots and domestic work. On their own plots of land, women across sites predominantly used manual irrigation technologies without help from their husbands or hired labor.

Nonetheless, while wary of the time and energy burden, women do express demand for mechanized irrigation technologies for greater financial independence and household food security. Initial evidence suggests which aspects of technologies women prefer. In Ethiopia, women did not want motor pumps because they added to their time burden, instead preferring solar pumps that could reduce both domestic and field labor requirements. Solar appears to be a promising technology for women (Burney, Naylor, and Postel 2013; McGrath 2015; FAO 2014; IRENA 2016). Nigussie et al. (2017) identified that women highly valued solar pumps located near the household where women have more control over information and production. Solar pumps with lower power capacity may limit the potential groundwater lifting rate but could be suitable for crops that women produce near the household. Multiuse pumps, sited in locations convenient for both men's and women's plots and compatible with different water application methods and uses of water, could be promoted so that men and women hold joint use and management rights over the same water-lifting technology, and women may have greater fructus rights over irrigated produce near the household. Further research into so-called female-friendly technologies should consider not only technological design that promotes women's use and management rights, such as labor and energy requirements or compatibility with accessible water sources, but also portability and location of installation that may affect women's fructus rights.

Fructus rights need to be systematically highlighted as both a gendered impact of technology adoption and a factor affecting motivation to try a new technology. Women face significant constraints claiming fructus rights but appear to value these rights the most and use different strategies to maintain them. Since men are likely to appropriate fructus rights if women exceed an income threshold, women opt for activities that generate lower sums of income sold continually over time rather than “lumpy” (large and infrequent) sales. Projects that attempt to shift women’s production to different crops or rapidly exceed a revenue threshold may risk women losing fructus and other rights. In addition, our findings regarding rice paddy warehouses in Tanzania indicated that fructus rights are particularly weak when there is strong information asymmetry over the sales of joint production. To balance women’s claims to fructus rights over such sales, approaches could include increasing women’s access to market information, joint financial services and mobile money services that provide alerts on transactions, or transparent and accessible documentation of sales.

More overtly transformative agricultural development projects attempt to shift norms within the household by forming groups of women and targeting women with assets and training. When successful, women recognize that this can strengthen their rights to a technology. However, our evidence shows that projects that attempt to target women, whether individually or in groups, fail if they do not first secure support from the men in their households. Men can block women’s participation or choose not to inform them of meetings. Demonstrating that women’s participation in such groups can benefit the whole family, save money, and potentially free women’s time for other activities may be a necessary first step to facilitate women’s involvement in these groups and subsequent awareness, tryout, and rights over a technology.

Our data suggest a need for further research to inform future technology adoption interventions. First, additional research is needed to examine whether the adoption modality affects the intrahousehold distribution of rights. Adoption modality includes several dimensions: whether technology is adopted by individuals or groups, who is involved in the decision to adopt, whether technology is purchased or received for free, and any accompanying social or household approaches that shift gender norms related

to the technology. Second, further investigation is needed into how different irrigation technologies—including their design, location, mobility, cost, and physical energy requirements—affect the distribution of rights, which technologies men and women prefer, and which rights are most important to them. Third, the relationship between women’s rights to technology and land rights needs to be further clarified. We focused here on women in married (male-headed) households where women depend on husbands for access to land, typically cultivating both a joint and independently managed plot. The framework may not apply as well to other settings, but as such is meant to guide inquiry into a specific context, rather than prescribe a universally applicable intervention approach.

Development partners promoting irrigation technologies to enhance resilience and increase productivity would benefit from understanding how technologies are used, by whom, and for what purpose. Some interventions assume that simply reaching women with technology—for example, distributing motor pumps to women—leads to their empowerment, without monitoring if or how this happens. Instead, identifying the distribution of rights can shed light on both the potential benefits and costs that adopting a technology confers to women and men within a household. This evidence will help ensure technology adoption strategically advances development objectives such as food and nutritional security, resilience, and women’s empowerment, rather than taking technology adoption as an end in and of itself.

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