INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

IFPRI

RESEARCH PROGRAM ON Policies, Institutions, and Markets

Led by IFPRI

IFPRI Discussion Paper 01920

April 2020

The Role of Interactive Radio Programming in Advancing Women's Empowerment and Crop and Dietary Diversity

Mixed Methods Evidence from Malawi

Catherine Ragasa

Diston Mzungu

Kenan Kalagho

Cynthia Kazembe

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI), a CGIAR Research Center established in 1975, provides research-based policy solutions to sustainably reduce poverty and end hunger and malnutrition. IFPRI's strategic research aims to foster a climate-resilient and sustainable food supply; promote healthy diets and nutrition for all; build inclusive and efficient markets, trade systems, and food industries; transform agricultural and rural economies; and strengthen institutions and governance. Gender is integrated in all the Institute's work. Partnerships, communications, capacity strengthening, and data and knowledge management are essential components to translate IFPRI's research from action to impact. The Institute's regional and country programs play a critical role in responding to demand for food policy research and in delivering holistic support for country-led development. IFPRI collaborates with partners around the world.

AUTHORS

Catherine Ragasa (c.ragasa@cigar.org) is a Senior Research Fellow in the Development Strategy and governance Division of the international Food Policy Research Institute (IFPRI), Washington, DC.

Diston Mzungu (mzungudiston@gmail.com) is a consultant.

Kenan Kalagho (ndaghamesho@yahoo.co.uk) is Gender officer at the Ministry of Agriculture, Irrigation and Water Development (MoAIWD), Kasungu District, Malawi.

Cynthia Kazembe (c.kazembe@cgiar.org) is a Research Officer at IFPRI's Country Strategy Support Program (CSSP) in Malawi.

Notices

ABSTRACT

The study assesses the effect of interactive radio programming on women's empowerment and agricultural development, employing nationally representative household panel data and qualitative interviews in Malawi. Four major findings can be highlighted. First, radio programming is the preferred source of agricultural and nutrition advice among many subpopulations: younger women and men used radio more than other sources for their agricultural information needs, while younger and older men used radio more than other sources for nutrition education. Second, results show a positive impact of radio programming on technology awareness but a limited impact on actual adoption of most agricultural practices being promoted, except crop residue incorporation. Third, results show positive impacts on dietary diversity and adoption of other nutrition practices among the rural population. Fourth, results show a strong association between access to interactive radio programming and women's and men's empowerment scores. The association is greater for women's empowerment and younger men's empowerment, the latter being the most disempowered group in the sample.

Keywords: agricultural extension, ICT, technology adoption, crop diversification, dietary diversity, gender

ACKNOWLEDGMENTS

This work was undertaken as part of the CGIAR Research Program on Policies, Institutions, and Markets (PIM) led by the International Food Policy Research Institute (IFPRI).

The authors acknowledge the financial support for the research and publication of this paper from the government of Flanders; the Gesellschaft fur Internationale Zusammenarbeit (GIZ, the development agency of the German government); the Strengthening Agricultural and Nutrition Extension (SANE) project, funded by the United States Agency for International Development (USAID) mission in Malawi as an activity of Feed the Future; and PIM.

We thank Wadonda Consult and the Lilongwe University of Agriculture and Natural Resources for assistance with data collection and focus group discussions. We are grateful to Dr. Catherine Mthinda for reviewing the early draft of this paper. Most importantly, we are grateful to all the people who shared their precious time with us during the surveys and interviews: the women and men farmers, community and group leaders, extension agents, extension organizations' officers and heads, development agencies' representatives, and government officials.

This paper is especially dedicated to the late Dr. Ephraim Chirwa, for his dedication in teaching and evidence-based policy solutions to development.

The opinions expressed herein belong to the authors and do not necessarily reflect those of Flanders, GIZ, SANE, USAID, PIM, IFPRI, or the CGIAR.

1. INTRODUCTION

The provision of useful, timely, and quality information and skills relevant to agricultural production, marketing, and climate resilience is crucial for agricultural development and rural transformation. However, delivering such information and skills to widely dispersed and diverse rural communities efficiently and cost-effectively remains a challenge. Whereas plenty of delivery tools and approaches are available, rigorous empirical evidence on whether and how those approaches work and under what conditions remains limited. Panel data analysis and randomized control trials are emerging to address this need (for example, BenYishay and Mobarak 2019; Kondylis, Mueller, and Zhu 2017; Larochelle et al. 2017; Fu and Akter 2016; Aker, Ghosh, and Burrell 2016; Aker and Ksoll 2016; Krishnan and Patnam 2014).

Various types of information and communications technology (ICT) are increasingly being evaluated for how they can be tapped to promote cost-effective and fast diffusion of information to rural communities (Larochelle et al. 2017; Fu and Akter 2016; Aker, Ghosh, and Burrell 2016; Aker and Ksoll 2016; Nakasone, Torero, and Minten 2014). Internet-based technologies (Young 2019; Roberts et al. 2017; Salemink, Strijker, and Bosworth 2017) and mobile platforms, text messaging, and telecenters (Lwoga and Chigona 2020; Larochelle et al. 2017; Fu and Akter 2016; Aker, Ghosh, and Burrell 2016; Aker and Ksoll 2016; Musafiri 2016; Chisama 2016; Nakasone, Torero, and Minten 2014; Katengeza, Okello, and Jambo 2011; Lwoga 2010) have been evaluated with mixed results as to their development impacts and inclusion. Radio, this paper’s focus, is among the more commonly used and accessible forms of ICT in rural areas and in the developing-country context.

Radio has been used for decades to disseminate information and provide education on agricultural practices (Chapman et al. 2003; Hambly, Odame and Kassam 2002; Fardon and Furniss 2000; Norrish 1998). Its use is widespread, with more than 55 percent of African households south of the Sahara listening to the radio weekly (Aker 2011), and figures in Malawi are even higher with more than 60 percent of households listening to radio at least once a week and 41 percent at least once daily (Ragasa and Niu 2017). In Malawi, more than half of women (52 percent) report listening to radio at least once a week. Radio has the advantage of being affordable and accessible even in remote areas and to poor women, although earlier radio programs promoting agricultural information have been criticized for their limited range of information and for the just one-way communication radio offers (Aker 2011). Radio is often compared with face-to-face visits, which are expensive but can offer intensive training and learning; and it has been compared more recently with the mobile phone and short text messaging, which are more expensive but can offer much more varied information and enable an interactive process (Aker 2011). But radio programming has evolved over time, and we now see various innovations that address earlier limitations, including interactive radio programming, linkages to call centers, mobile applications (WhatsApp), and listening clubs, in addition to other combinations.

Compared with more advanced types of ICT, such as mobile- and Internet-based information systems, radio programming has been more rarely evaluated rigorously given the difficulties in controlling access to radio stations in a randomized control trial context or rarity of large-scale panel datasets. Recent evaluations of interactive radio programming and participatory radio campaigns have been positive about the role of radio programs in rural areas, although the evidence is limited to pilot cases with small sample sizes and qualitative case studies (Zossou and Demont 2019; Hampson et al. 2016; Yadav et al. 2017; Hudson et al. 2017; Kelemu, Haregewoin, and Daniel 2016). A recent multicase study assesses the role of radio-based information services versus other information services for promoting climate-smart agriculture (Westermann et al. 2018). Our paper aims to build on these studies and contribute to the literature by (1) using both a unique nationally representative household panel dataset and rich qualitative data to evaluate interactive radio's role in knowledge diffusion and agricultural and rural development; (2) paying close attention to the intersectionality of gender, age, economic status, and geographical location in analyzing the impact of radio programming; and (3) analyzing the effects of radio programming in comparison to other information and extension services.

Interactive radio programming is quite popular in Malawi, and Farm Radio Trust (FRT) in Malawi has been very active in agricultural extension provision. FRT and partners have experimented with different ways to improve its delivery of messages to farmers. FRT provides guidance to national and community radio stations about messaging on agriculture, nutrition, and climate change.

Our aim is to evaluate the impact of interactive radio programming in Malawi. The contribution of radio programming in Malawi has been cited in project reports; however, those are project reports or case studies, and no systematic or quantitative impact assessment has been done to date. We aim to fill that gap by assessing the impact of the innovations in agricultural radio programming in Malawi using nationally representative household panel data (2016 and 2018) in combination with qualitative data. The specific research questions are as follows:

1. Does access to radio messaging have an impact on awareness and adoption of climate-smart agricultural practices?

2. Does access to radio messaging have an impact on crop diversification and dietary diversity?
3. Does differential access to radio by women and men have an effect on technology awareness and adoption, crop diversification, and dietary diversity?
4. Is access to radio programming associated with greater women's empowerment?

Malawi's nationwide implementation of interactive radio programming offers a unique setting in which to assess the effectiveness and sustainability of approaches when scaled up. Often, pilot donor projects are well supported and extension workers or lead farmers are provided with per diems, transportation allowance, and input supports. However, when such projects are scaled up and institutionalized nationally, with government oversight characterized by limited resources and weaker monitoring, we see different results from the pilot cases. The availability of a nationally representative panel dataset that includes details on awareness of and adoption of agricultural and nutrition practices and various extension approaches, among them radio programming, provides a unique opportunity to analyze these issues. We describe interactive radio programming in Malawi in the following section and present our data sources and methods in the third section. Subsequent sections provide the results of the descriptive analysis, results of the regression analysis, a discussion of the implications of the results, and concluding remarks.

2. INTERACTIVE RADIO PROGRAMMING IN MALAWI

Interactive radio programming was piloted in Malawi in 2015 by Farm Radio Trust–Malawi (FRT) and the government's Department of Agricultural Extension Services. It consists of radio messaging over national and community radio stations. Various radio stations serve the rural communities, so farmers can choose which stations they prefer to listen to. Messaging is usually year-round with the greatest intensity during planting season. In general, the broadcasts are daily, with the duration of agricultural messages varying from 30 minutes to two hours. FRT's role is to provide assistance and harmonize the messaging for the radio stations.

Aside from the radio messaging, Malawi has seen four additional, complementary innovations:

- A call-in center, which anyone can call for free, captures farmers' demands and concerns on any agricultural topic daily.
- A mobile platform, on which anyone can text for free, also helps in capturing farmers' issues and demands for information.

- Videos and short text messages are usually sent via mobile phone, with a focus in 2016–2017 on six districts: Balaka, Blantyre, Chikwawa, Mangochi, Nsanje, and Zomba.
- Listening clubs or ICT hubs introduce ICT to existing farmers' groups, also with a focus in 2016–2017 on the aforementioned six districts. In those districts, 1,500 battery-powered radios and 500 solar panels were distributed.

Radio messaging since 2015 has focused on good agricultural management practices for groundnuts, soybean, and orange-fleshed sweet potato, with emphasis on aflatoxin control, Purdue Improved Crop Storage (PICS) bags, inoculants, and climate adaptation strategies. We could expect to see impacts on knowledge and awareness of these promoted technologies, adoption of the technologies, and productivity, which would mean households enjoying more food security and diversity and more surplus crops available to sell and earn income. The messaging also addresses dietary diversity, nutrition, and health, and therefore we could expect outcomes with regard to household dietary diversity. Lastly, messages are also broadcast on gender issues—for example, using jingles or dramas—and therefore we might expect to see some changes in women's empowerment and gender parity. Mechanisms for this gendered outcome may be through a lower time burden (compared with time demands for attending trainings or meetings, women can listen to radio and learn while simultaneously doing their other work) and through messages on gender equality that can influence both male and female listeners and therefore potentially lead to changes in attitudes and behavior. Therefore, this paper aims to evaluate the impact of interactive radio programming, in the context of Malawi, on the following outcomes:

- Crop diversification, especially the promotion of legumes, away from maize or tobacco
- Awareness and adoption of the promoted climate-smart agricultural practices
- Nutrition, focusing on dietary diversity
- Gender equality and women's empowerment

3. DATA SOURCES AND EMPIRICAL STRATEGY

3.1. Data Sources

The study draws from various sources of data, both quantitative and qualitative. First, it uses nationally representative household data collected from August to October 2016 (wave 1) and from July to September 2018 (wave 2) by the International Food Policy Research Institute (IFPRI). The surveys covered all of Malawi's districts except Likoma. In each district, probability-proportional-to-size sampling was used to determine the number of communities and households to randomly select. Within each selected district, sections were randomly selected, and within those, communities were randomly selected. Ten households were interviewed in each selected community. In total, the first wave covered 3,001 households and the second wave covered 2,880, with very small attrition (4 percent). We have a total of 5,542 pooled observations for the two periods with balanced and complete data for all the variables used in the paper. See Ragasa and Niu (2017) for more details of the sampling method.

Complementing the household surveys are community surveys, with two to four village leaders and opinion leaders responding, and focus group discussions (FGDs), comprising six to eight farmer-participants. A total of 22 gender-disaggregated FGDs were conducted in January and February 2017. Most of the communities were revisited in January 2019, while others were added totaling 30 FGDs in 2018. In total, 52 FGDs representing 113 male and 141 female respondents were sampled from 11 communities in eight districts from the same geographic areas as the household and community surveys. Figure 1 illustrates the locations of the focus group discussions. The eight districts were sampled purposively using a maximum variation approach to capture different agroecological and social characteristics, such as soil type, main crops produced, and dominant tribe. Two communities from each of the districts were randomly sampled from the survey population, one very remote and one more central, as we hypothesized that quality and frequency of service delivery might differ according to remoteness. Adults from households (six to eight per community) were purposively sampled based on different headship and wealth characteristics. However, fewer men were willing to participate, decreasing somewhat the number and variation of the sample of men. Local enumerators fluent in the local Chichewa, Chibandya, and Chinyika languages led the FGDs. Enumerators were experienced in qualitative data collection and were asked to encourage the active participation of all and the articulation of differing views among participants. Discussions were recorded, transcribed, and translated, and then thematically coded using NVivo 11.

Figure 1. Map of Malawi and locations of the focus group discussions and districts covered in the household and community surveys used in this paper

Source: IFPRI surveys (2016, 2018), which cover all districts (except Likoma), and 52 focus group discussions conducted by IFPRI in January–February 2017 and January 2019 in 11 communities in eight districts, as marked above. The areas shaded blue are bodies of water.

3.2. Empirical Model

Our study's main goal is to model the contribution of interactive radio programming to the adoption of agricultural technologies and management practices that are being promoted and changes in other development outcomes in Malawi. The radio programing is offered nationwide as a natural experiment, and therefore there is no counterfactual or control group to enable a more formal impact evaluation. While the radio programming is offered to all districts, not all farmers avail themselves of or listen to agricultural messaging and not all have radio (not all are listeners). We are interested in evaluating the impact on agricultural behavior of listening to agricultural radio programming. Table 1 presents the outcome variables used in the study, their measures and definitions, and their descriptive statistics.

Table 1. Definition of outcome indicators

Indicator	Definition and Measurement	Unit of Observation
Awareness of climate-smart agricultural practices	Binary variable on whether a household is aware of or has knowledge about the following practices being promoted: soil cover or mulching, minimum tillage or minimum disturbance of the soil, intercropping or crop rotation, pit planting, manure or fertilizer making, and crop residue incorporation	Household
Adoption of climate-smart agricultural practices	Binary variable on whether a household has adopted and the percentage of acreage where the practice was adopted	Household
Acreage for legumes	Total acreage planted with legumes; and percentage of acreage planted with legumes	Household
Crop diversification index	$SID_i = 1 - \sum_{j=1}^{J_i} c_{ij}^2$ Simpson's crop diversification index where c_{ij} is household i's share of the total cropland area that is planted with crop j, $j = 1, \dots, J_i$	Household
Dietary diversity	Number of distinct food groups the household has eaten in the last 24 hours	Household
Women's empowerment	We adopted five of the A-WEAI's six domains, excluding time use; we used alternative questions for time constraint	Individual
Gender parity	Defined as the woman's empowerment score not lower than the man's within the household	Household

Source: Authors' compilation based on IFPRI surveys (2016, 2018)
Note: A-WEAI = abbreviated Women's Empowerment in Agriculture Index.

Household-level: Technology awareness and adoption

Numerous studies model farmers' decision to adopt or not adopt certain agricultural technologies and management practices based on several factors (see Foster and Rosenzweig 2010). More recent papers on technology adoption have modeled the adoption decision as a stepwise process, starting with discovery, exposure or awareness, and then trying out the technology (Kabunga, Dubois, and Qaim 2012; Lambrecht et al. 2016). We analyze adoption by a smallholder farmer *i* as a two-step process consisting of awareness and adoption. The model is specified as follows:

Awareness: $Y_{iAw} = 1[\beta'_{Aw} X_{ij} + \gamma_{Aw} Radio_i + \varepsilon_{iAw} > 1]$ (1)
= 0, otherwise

Adoption: $Y_{iAd} = 1[\beta'_{Ad} X_{ij} + \gamma_{Ad} Radio_i + \varepsilon_{iAd} > 1]$ if $Y_{iAw} = 1$ (2)
= 0, otherwise

We use the binary outcome variable Y_{iAw} for awareness and both binary and continuous variables Y_{iAd} for adoption during that cropping season of agricultural technologies or management practices that are disseminated by radio in the farmers' communities. $Radio_i$ is the variable of interest that describes listening to agricultural radio programming, and X_{ij} is a vector of explanatory variables. All of these are defined below, and the descriptive statistics are shown in Table A1.

We define awareness as a farmer being aware of or having knowledge about a specific technology or management practice. The survey question was "Are you aware or have knowledge of the following technologies and practices?*"* For adoption, we use two measures of adoption: (1) self-reported adoption for at least two seasons from a list of predetermined technologies and practices (in the technology awareness module); and (2) self-reported management practices and input use in the particular plot for the cropping season (in the plot-level production module). If a farmer practices technology *x* in any of his or her plots we consider it adopted. Both measures of adoption were largely consistent. We also computed the intensity of adoption, measured in terms of percentage of total acreage in which a particular technology or practice was adopted.

We chose technology packages and practices that are commonly promoted as low-cost and climate-smart, namely, soil cover or mulching, minimum tillage or minimum disturbance of the soil, intercropping or crop rotation, crop diversification, pit planting, composting pits, manure or fertilizer making, crop residue incorporation, bunds, and water management. The latter is mainly rainwater harvesting in box ridges, swales, pits, or tanks. These practices help manage soil fertility and moisture retention to adapt to climate change.

We focus on management practices rather than external inputs so as to isolate issues of credit or capital availability and examine the extent of informational failures in low adoption of low-external-input management practices. We excluded herbicide, even though it is part of the conservation agriculture package for some promoters (Holden et al. 2018; Ragasa and Niu 2017). In Malawi, few farmers use herbicide given that it is very expensive, and there was not much variation in such herbicide adoption to use and model for the purposes of this paper.

Household-level: Crop diversification, legumes acreage, and dietary diversity

Other outcome variables are continuous, count, or fractional response data at the household level, including crop diversification, acres planted with legumes, percentage of total crop area planted with legumes, and household dietary diversity.

To account for time-invariant unobserved heterogeneity, we estimate fixed effects, random effects, and correlated random effects (CRE) models. The fixed effects model is estimated using the following estimating equation:

$$Y_{it} = \alpha_i + \beta_1 1(Radio)_{it} + X\beta_2 + \gamma_t + \epsilon_{it}, \tag{1}$$

where Y_{it} is household i's level of crop diversification, legume acreage, percentage of legume acreage, and dietary diversity score at year t, $1(Radio)_{it}$ is an indicator for whether household i received radio extension services from any source at year t, X is a vector of controls, α_i are household fixed effects, and γ_t are year fixed effects. The CRE model is estimated using the following estimating equation:

$$Y_{it} = \alpha + \beta_1 1(Radio)_{it} + X\beta_2 + \beta_3 \overline{1(Radio)}_i + \bar{X}\beta_4 + \epsilon_{it}, \tag{2}$$

where $\bar{X}$ is the household-level mean of the control variables, and $\overline{1(Radio)}_i$ is the household-level mean of the extension indicator. For fractional response, we used CRE fractional logit.

Individual-level: Women's empowerment

An outcome variable measured at the individual level is women's empowerment. We measure women's input in productive decisions, ownership of assets, access to credit, control over use of income, and group membership—similar to the abbreviated Women's Empowerment in Agriculture Index (A-WEAI) (see Malapit et al. 2017). The A-WEAI survey instrument reflects all five domains of empowerment in agriculture using six indicators. With regard to the time domain, we use alternative questions to measure time constraints:

- If you wanted to do something (livelihood related, training related, self-care), will you be able to reorganize your tasks so that you can make time to do it?
- If you wanted to do something (livelihood related, training related, self-care) and could not take your child with you, is there someone who could care for your child in your absence?

Household-level: Gender parity

Lastly, at the household level, we compute and model gender parity. For this we use a binary variable defined as the woman's empowerment score being not lower than the man's within the household.

Variable of interest: Listening to agricultural radio programming

We used the household survey responses to the following questions to generate our radio programming access:

1. "In the last 2 years [In the last 12 months], did you receive any information or advice on any of these topics?"
   - ➔ *[If YES, "From which sources did you receive information or advice about agriculture or nutrition in the last 2 years (in the past 12 months)?" [radio is one of the choices]*
2. "In the last 12 months, have you participated in any of these activities or used any of these methods to get information on agriculture or nutrition?" *[radio is one of the choices]*

From the above, we generated and used the following indicators:

- Whether the individual received agricultural advice from radio programming in the last two years (0/1)
- Whether the individual received agricultural advice from radio programming in the last 12 months (0/1)
- Whether the individual used agricultural radio programming for agricultural information in the last 12 months (0/1)

At the household level, we define household access by whether anyone in the household had access to radio programming. We also create another variable that looks at the gender of the listener and whether that contributes to better outcomes.

Control variables ($\boldsymbol{X_{ij}}$)

We control for other sources of information (namely, government extension, nongovernmental organization [NGO] extension, lead farmers, other farmers, and phone/SMS [short message service]) and delivery methods (namely, farmer field days, farm demonstrations, printed materials, phone/SMS, community/group meetings, group village agricultural development committees [GVACs], and village agricultural development committees [VACs]). Various household-, community-, location-, and climate-related characteristics can influence technology adoption (see Table A1). Among the household-level variables, we included indicators of financial, physical, human, and social capital. We measure financial capital and wealth by a household asset index, calculated using principal components analysis based on dwelling roof material, dwelling wall material, and the number of air conditioners, radios, cellphones, tape or CD players, televisions, refrigerators, washing machines, bicycles, motorcycles/scooters, cars, ox carts, power tillers, and tractors, largely based on and adopted from the Malawi Integrated Household Survey questionnaire. Alternatively, the value of these assets during the time of the survey was also used. Physical land capital is measured by total land acreage. Human capital indicators include years of education of the household head, age of the household head and its square, household size, and the number of laborers in the household. Social capital indicators include membership in groups or organizations.

3.3. Estimation Strategy

Panel data analysis

We used several strategies and estimation approaches to address nonexposure bias (Diagne and Demont 2007; Kabunga, Dubois, and Qaim 2012), nonrandom program placement and selection bias (Feder, Just, and Zilberman 1985), and potential unobserved heterogeneity issues (Ragasa and Mazunda 2018). First, we address nonexposure bias by implementing a two-step process, modeling adoption conditional on awareness. This is done by limiting the adoption model to only those who are aware.

Second, to address selection bias and unobserved heterogeneity we apply the Mundlak-Chamberlain (MC) device (Mundlak 1978; Chamberlain 1984), also known as a correlated random effects (CRE) model.[1] MC/CRE approach allows for correlation between the unobserved individual omitted variable and the variable of interest (receipt of extension services), provided the unobserved effect is time-invariant. The MC/CRE device allows for modeling the distribution of the omitted variable conditional on the means of the strictly exogenous variables, instead of treating the omitted variable or heterogeneity as a parameter to estimate. To implement the MC/CRE device, we include the means of all time-varying covariates for the household. These averages have the same value for a given household in every year but vary across households.

[1] An alternative to the MC/CRE approach is a fixed-effects model. However, fixed effects models are generally inconsistent in nonlinear models as the number of observations (*N*) grows with fixed time (*T*) as in our case (since we have only two years of data) (see Wooldridge 2019; Papke and Wooldridge 2008). As experts have noted, fixed effects models in short panels are generally not estimable due to the incidental parameters problem (Wooldridge 2019; Papke and Wooldridge 2008). Experts recommend an MC/CRE model for shorter time series (Woodridge 2019; Papke and Wooldridge 2008). In general, the MC/CRE device unifies the fixed effects and the random effects estimation approaches. By including the vector of time-averaged variables, we still control for time-constant unobserved heterogeneity, as with fixed effects, while avoiding the problem of incidental parameters in nonlinear models. At the same time, the MC/CRE device allows measurement of the effects of time-constant independent variables, just as in a standard random effects environment (Wooldridge 2002; Papke and Wooldridge 2008; Wooldridge 2019).

Third, for awareness and adoption of technologies (binary response), we use MC/CRE. For intensity of adoption, that is, the percentage of crop area on which the specific technology was adopted, which is a fractional response from 0 to 1, we extend the CRE to account for the fractional responses in the intensity of adoption, using multivariate weighted nonlinear least squares or the related generalized estimating equation (GEE) (using the *xtgee* command in Stata). For a sensitivity check, we ran fixed effects models for the intensity of adoption, where the outcome variables are continuous, although bounded from 0 to 1 (see Table 5). We used the Hausman test to check the consistency and efficiency of standard random effects (linear) and MC/CRE (linear) versus fixed effects (linear). In most of these models, we reject the null hypothesis that standard random effects (linear) is consistent and more efficient than fixed effects (linear); however, we cannot reject the null hypothesis that CRE is consistent and more efficient than fixed effects, as shown in the Hausman test. This is another proof of the efficiency gains of using CRE versus fixed effects (linear) or standard random effects (linear).

Fourth, given the multitude of sources and delivery methods available to rural communities and households, we model the effect of access to radio programming relative to other sources and delivery methods. The focus technologies are not specific to the radio programs—that is, several NGOs and government extension agents are working in similar communities to disseminate these technologies through other delivery methods (such as face-to-face visits, community/group meetings, or the lead farmer approach). In our study we hope to evaluate the contribution and the role of radio programming in accelerating, scaling out, and widening the outreach and coverage of these technologies relative to other sources and delivery methods. The aim is to see whether gaps exist that radio programming can fill in relative to other sources and delivery methods, and where and when it fills those gaps.

Lastly, given that some components of interactive radio programming—ICT hubs or listening clubs, sending videos via mobile apps, and distribution of battery-powered radios—were first piloted in Balaka, Blantyre, Chikwawa, Mangochi, Nsanje, and Zomba (treatment groups), we match these treatment districts with similar districts. The selection of comparable groups is based on expert knowledge and indicators of similarities, including suitability for legume production, agroecology and farming systems, and implementation of agricultural programs/projects in those districts (the rest of the districts in the Southern Region) (control groups). We compare the effects of listening to radio programming on various outcome variables between the treatment and control groups.

We complemented the MC/CRE and fractional MC/CRE methods with Heckman selection probit and bivariate probit models to check for robustness and consistency of results. Altogether, these three methods show consistent results. In this paper, we show only the MC/CRE model results since they are largely similar to the results of the Heckman selection probit and bivariate models.

Cross-sectional data analysis using matching techniques

For women's empowerment and gender parity, we collected data from only one period (2018). We use matching techniques to calculate the average treatment effects. To match treatment and control households, we use nearest neighbor matching and kernel matching, two algorithms commonly used for empirical analysis (Caliendo and Kopeinig 2008). In addition, we use another set of matching techniques, stratification using propensity scores and inverse-probability-of-treatment weighting (IPTW), to further check the consistency of results across different matching methods. IPTW is particularly useful to reduce selection bias in studies with observational data and produces unbiased estimates with small samples (Pirracchio, Resche-Rigon, and Chevret 2012; Hirano and Imbens 2001). We show the balancing and bias reduction tests from the different estimation methods in Appendix Table A2. As shown in Appendix Table A2, the matching techniques substantially reduced the selection bias based on observable characteristics.

It should be stressed that matching techniques build on the assumption of conditional independence, which is also called *selection on observables* (Rosenbaum and Rubin 1983). This means that the method controls only for observed heterogeneity between treatment and control households. Estimates of the average treatment effect on the treated may still be biased in the presence of unobserved heterogeneity. We test for the influence of such hidden bias by calculating Rosenbaum bounds (Becker and Caliendo 2007; DiPrete and Gangl 2004). Our estimations show that the critical value for bias from unobserved heterogeneity is high (more than 4 in most cases), indicating that the results are not sensitive to bias caused by unobserved heterogeneity. The lower bound of greater than 4 means that matched households with the same observed covariates would have to differ in terms of unobserved covariates by a factor of more than 4 in order to invalidate the inference of a significant treatment effect. This shows confidence in the estimates.

4. DESCRIPTIVE ANALYSIS

4.1. Technology Awareness and Adoption, Crop Diversification, and Dietary Diversity

Farmers' awareness of all of the technologies, except for fertilizer or manure making, generally improved from 2016 to 2018 (Appendix Table A1). We also see improvement in the adoption of some technologies, although adoption of other technologies decreased. Major improvement is seen in the adoption of bunds/ridges, crop residue incorporation, organic fertilizer use, water management, and intercropping, but we see no improvement in soil cover or mulching, minimum tillage, or pit planting.

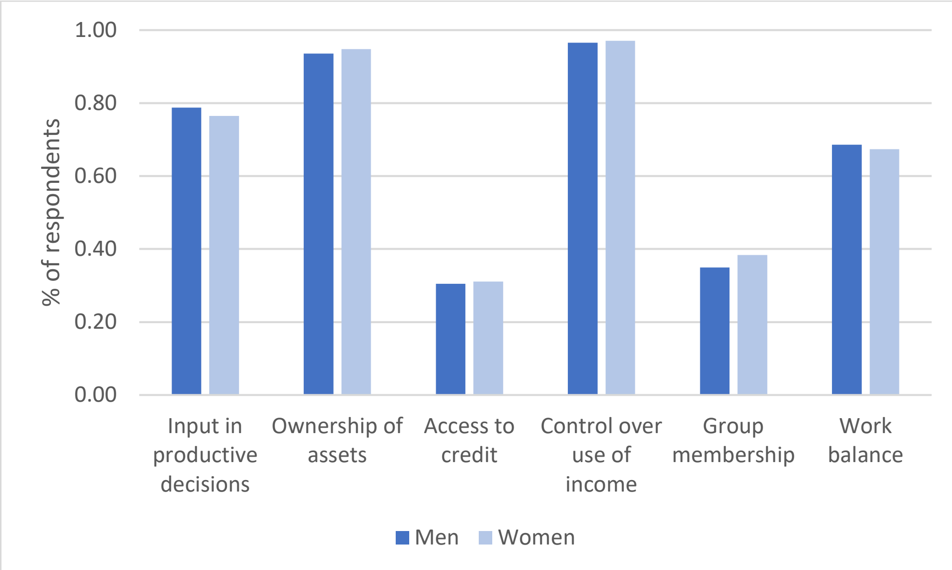
A huge gap exists between those who were aware of the practices and those who adopted them (Appendix Table A1). That gap is what our econometric models that follow try to explain. Conditional on being aware or knowledgeable, we model later in the paper whether listening to agricultural radio programs contributes to explaining the gap between awareness of and adoption of the major agricultural practices being promoted.

We see a slight increase from 2016 to 2018 in the crop diversification index, the percentage of total crop acreage planted with legumes, and household dietary diversity. Legume acreage stayed almost the same at 0.58 acres per household on average.

4.2. Women's Empowerment

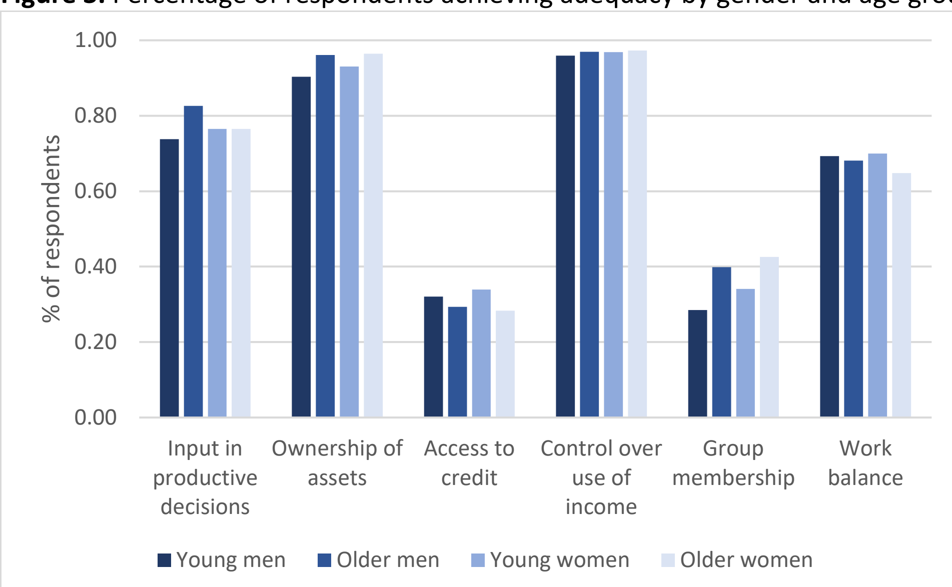
As Figure 2 shows, the empowerment scores of women and men are similar. For both women and men, a lack of access to credit and weak group membership are the major sources of disempowerment. These results are largely consistent with those of earlier surveys in Malawi using the WEAI in 10 districts of the USAID Feed the Future program (FTF FEEDBACK 2013, 2015). Young men are relatively more disempowered in terms of lack of input in productive decisions (Figure 3). Young men and women are relatively more disempowered in terms of weak group membership. Older women are relatively more disempowered in terms of heavier workload. Older men and women are relatively more disempowered in terms of lack of access to credit. Young men are the least empowered, followed by young and older women, while older men are the most empowered (Figure 4).

Figure 2. Percentage of respondents achieving adequacy by gender



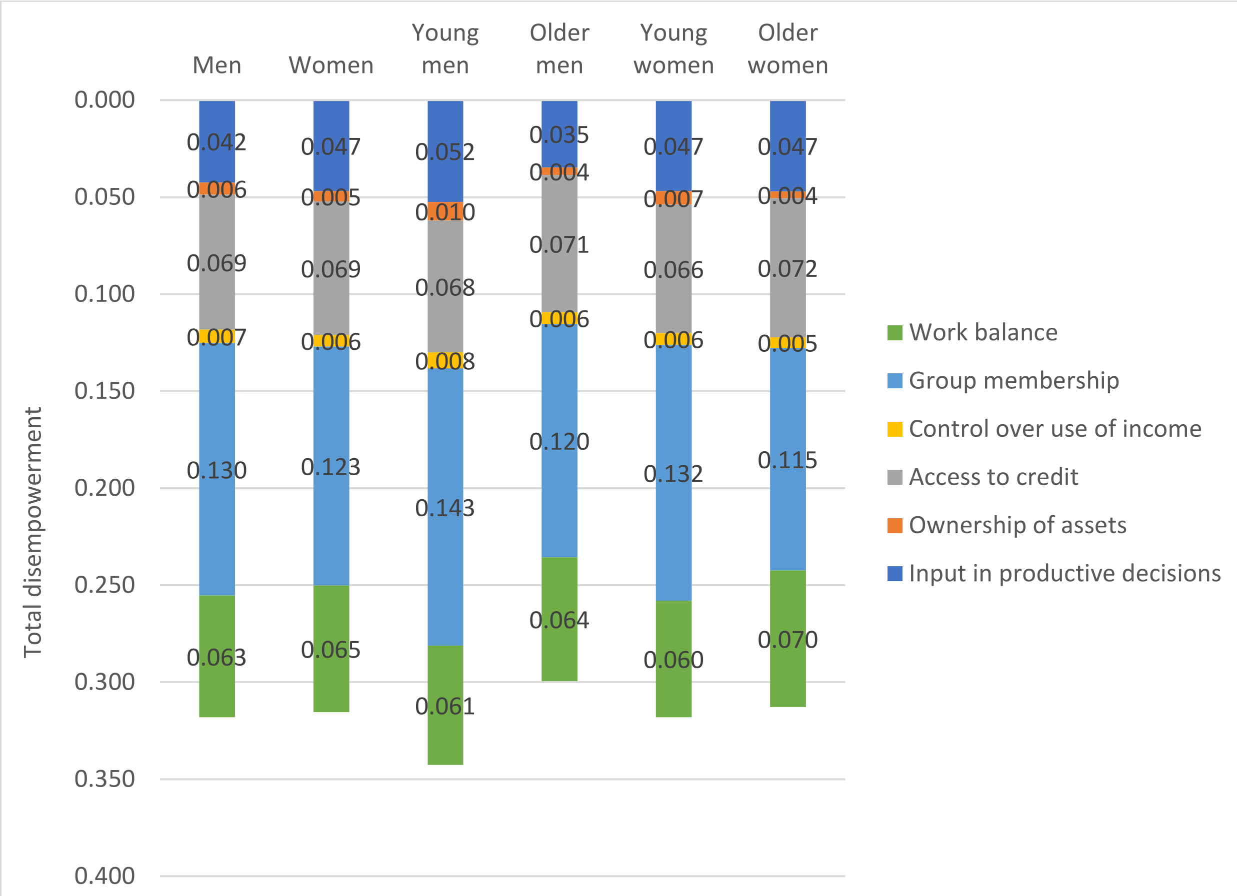
Source: IFPRI household survey (2016, 2018).

Figure 3. Percentage of respondents achieving adequacy by gender and age group



Source: IFPRI household survey (2016, 2018).

Figure 4. Contributors to disempowerment

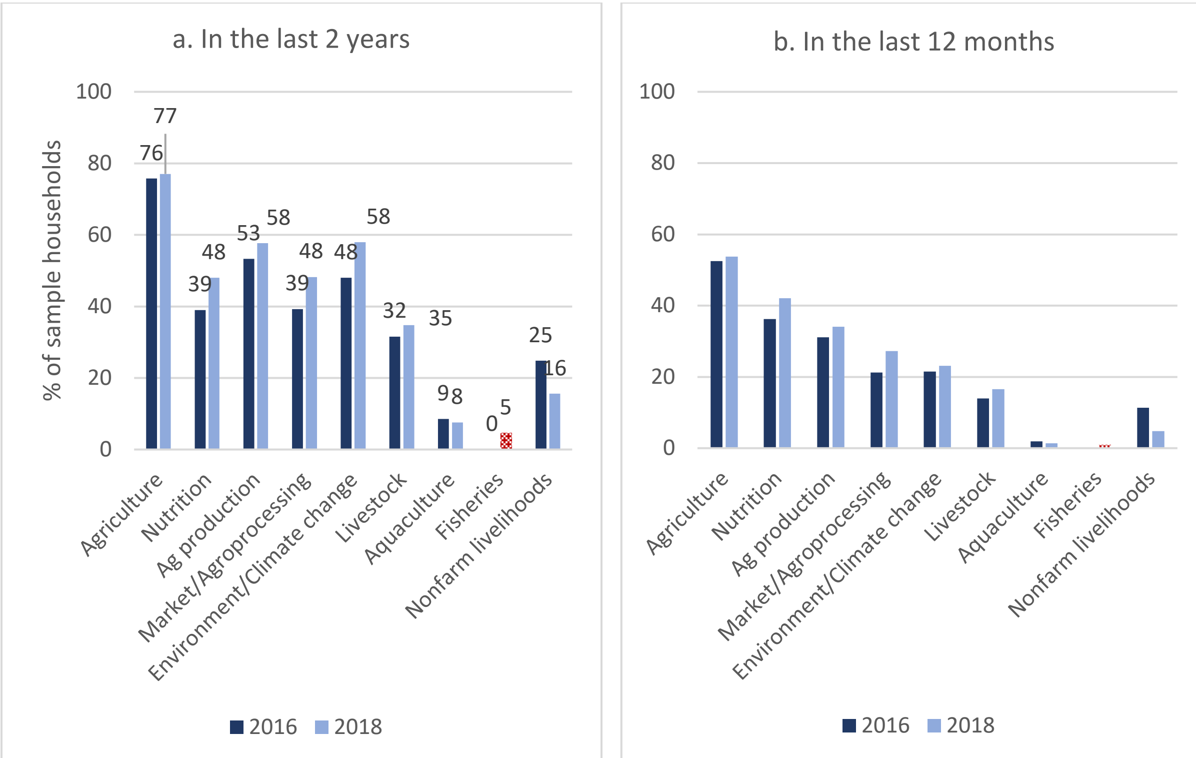


Source: IFPRI household survey (2016, 2018).

4.3. Access to Extension Services

Seventy-seven percent of the households reported access to any agricultural advice in the last two years—a fairly high mark (Figure 5, panel a). Both agricultural and nutrition advice are not frequent and do not come yearly as we see a large difference between access to advice within a two-year duration (panel a) versus a one-year duration (panel b). In panel b, 54 percent of the households reported access to agriculture advice in 2018—only a 1 percent increase from 2016. Improvement between 2016 and 2018 is seen mainly in access to marketing/agroprocessing and environment/climate change.

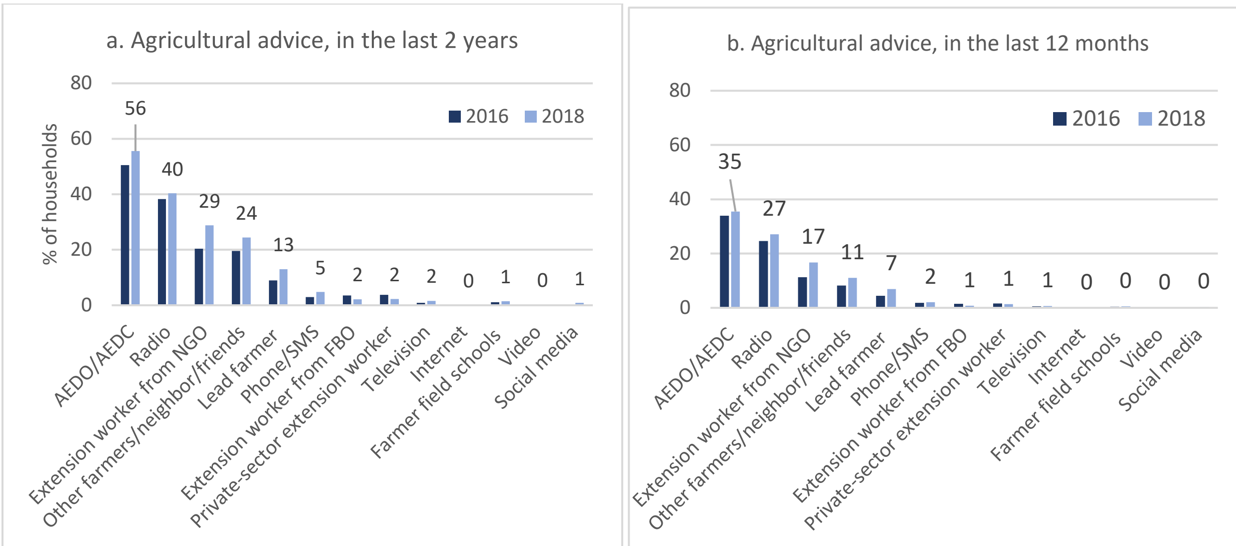
Figure 5. Percentage of households receiving agricultural or nutrition advice from any source, 2016 and 2018



Source: IFPRI household survey (2016, 2018).
Note: Agriculture (the first item) combines all non-nutrition-related advice, including advice on crop production, market/agroprocessing, environment/climate change, livestock, aquaculture, fisheries, and nonfarm livelihoods. The dotted red bar (fisheries) indicates that only 2018 data were collected on this subject. Survey question: "In the last 2 years [In the last 12 months], did you receive any information or advice on any of these topics?"

The main source of agricultural advice was government extension workers (agricultural extension development officer or agricultural extension development coordinator), followed by radio, NGO extension workers, other farmers, lead farmers, and phone/SMS (Figure 6). We see a slight increase from 2016 to 2018 in the percentage of households receiving advice from all these sources, excepting extension workers from farmer-based groups or organizations and the private sector. The most noticeable improvements are seen in more households reporting receiving agricultural advice via NGO extension workers, other farmers, lead farmers, and SMS/phone.

Figure 6. Percentage of households receiving agricultural or nutrition advice from specific source, 2016 and 2018



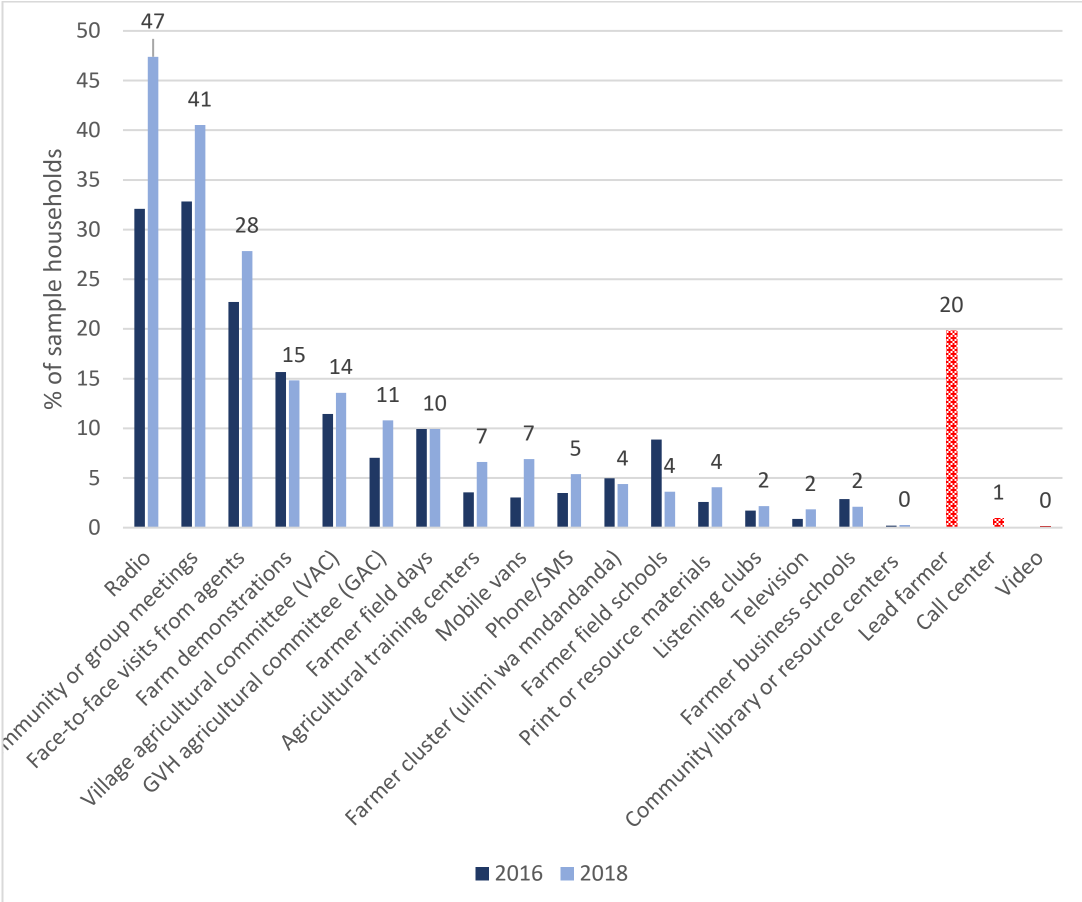
Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: Survey question: "From which sources did you receive information or advice about agriculture or nutrition in the last 2 years (in the past 12 months)?"
AEDO/AEDC = agricultural extension development officer/agricultural extension development coordinator; NGO = nongovernmental organization; FBO = farmer-based organization.

As Figure 7 shows, among the surveyed households, radio is the main method of receiving agricultural or nutrition advice (48 percent of households). The next most prevalent are community or group meetings and face-to-face visits from extension agents. These have consistently been the primary methods of receiving advice in both 2016 and 2018. The greater access to agriculture- or nutrition-related advice observed in 2018 seems to be driven by increases in access through radio, community/group meetings, and face-to-face visits from extension agents.

Other communication methods showing slight improvement in terms of households reporting using them are VACs or GVACs, training centers, mobile vans, mobile phones/SMS, print materials, and television shows. However, we see slight decreases in the percentages of households reporting participation in farm demonstrations, farmer clusters, farmer field schools, and farmer business schools.

Listening clubs or ICT hubs are not yet popular nationwide, with only 2 percent of households belonging to an ICT hub or listening club per the national survey. Similarly, neither call-in centers nor videos are as yet popular with only 1 percent and less than 1 percent, respectively, using them. In the treatment districts, where these services have been mainly promoted in 2015–2017, we see slightly higher coverage, but coverage is still small compared with that in the control districts. In the treatment districts 3 percent of households report membership in a listening club or ICT hub versus 1 percent in the control districts. Similarly, call-in center users make up 3 percent of the total sample in the treatment districts and 1 percent in the control districts.

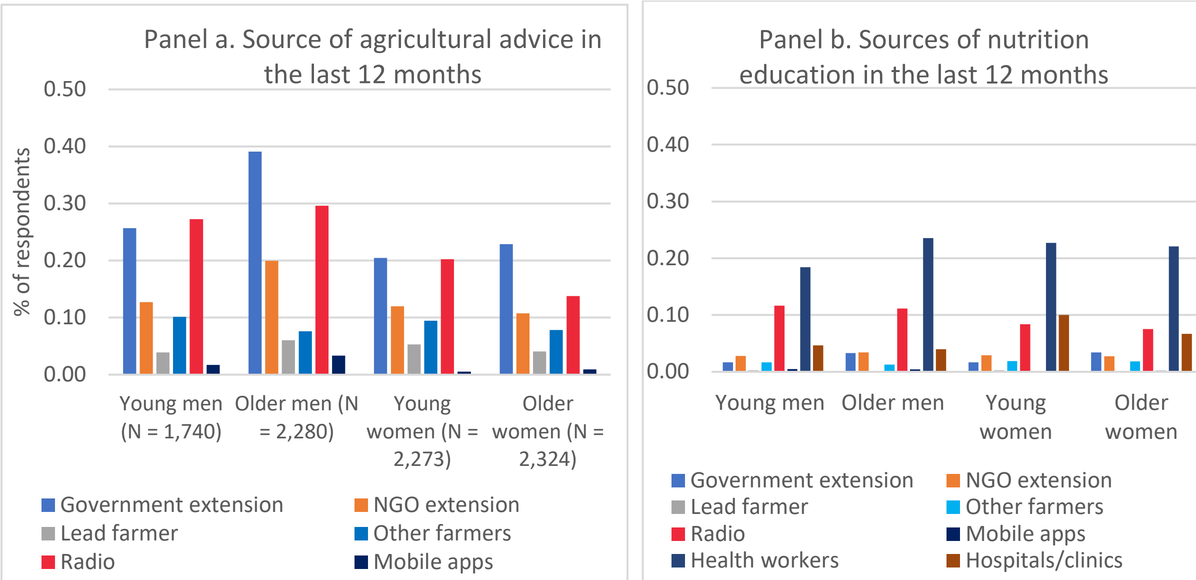
Figure 7. Percentage of households using or participating in various extension methods or approaches



Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: The dotted red bar (lead farmer, call center, video) means that data were collected only in 2018. GVH = group village head SMS = short message service. Survey question: "In the last 12 months, have you participated in any of these activities or used any of these methods to get information on agriculture or nutrition?"

In terms of gender of the receiver of the agricultural information, men have greater access to almost all sources of agricultural advice (Figure 8). This is consistent with the literature highlighting women's limited access to agricultural extension services and technologies compared with men (Ragasa 2014; Achandi et al. 2018). Older men have the greatest access to most sources of agricultural advice. Compared to other sources (for example, government extension), radio is the top source for young men and women. Women have greater access to most sources of nutrition advice. This is consistent with earlier studies (for example, Ragasa, Aberman, and Alvarez-Mingote 2019). Surprisingly, men (both young and older) have greater access to nutrition advice from radio compared with other sources and compared with women.

Figure 8. Gender of the direct receiver of the agricultural information



Source of raw data: IFPRI household survey (2016, 2018). N=number of respondents

5. REGRESSION ANALYSIS

5.1. Technology Awareness and Adoption, Crop Diversification, and Dietary Diversity

Listening to radio programming has a consistently positive impact on technological awareness. In particular, it increases the likelihood of a person's awareness of soil cover, pit planting, water management, bunds, and manure or fertilizer making by 3 to 10 percent (Tables 2 and 3). We also see consistently positive impacts of listening to radio programming on the likelihood and intensity of adoption of crop residue incorporation, but not for any other agricultural practices (Tables 2 through 5). Listening to agricultural radio programming increases the likelihood of awareness of crop residue incorporation by 9 percent, the likelihood of adoption of it by 11 percent (Table 4), and the intensity of adoption of crop residue incorporation by 4 to 9 percent (Table 5).

There is no significant effect of radio messaging access on crop diversification and legume acreage (Tables 6 through 9), but we see a consistently significant effect of radio programming on household dietary diversity (Tables 10 and 11). Listening to radio programming increases the household dietary diversity score by 0.18 to 0.35 score points.

Table 2. Effects of radio programming and other sources of agricultural information on the likelihood of technology awareness of and adoption of major agricultural practices

	Soil cover		Minimum tillage		Intercropping		Pit planting	
	Aware	**Adopt**	**Aware**	**Adopt**	**Aware**	**Adopt**	**Aware**	**Adopt**
Received advice in last 2 years								
Radio	**0.060*** **	**-0.018**	**0.003**	**-0.000**	**0.007**	**(0.026)**	**0.035***	**(0.001)**
	(0.021)	**(0.026)**	**(0.022)**	**(0.016)**	**(0.022)**	**(0.021)**	**(0.020)**	**(0.022)**
Government	0.057***	0.014	(0.009)	(0.026)	0.005	(0.002)	0.043**	(0.009)
	(0.021)	(0.029)	(0.022)	(0.018)	(0.023)	(0.022)	(0.021)	(0.024)
NGO	0.051**	-0.051*	0.061**	(0.021)	0.098***	(0.039)	0.066***	(0.004)
	(0.023)	(0.027)	(0.025)	(0.016)	(0.027)	(0.024)	(0.023)	(0.022)
Lead farmer	0.111***	0.118***	(0.052)	0.012	0.011	0.018	0.008	(0.008)
	(0.031)	(0.036)	(0.033)	(0.019)	(0.033)	(0.034)	(0.030)	(0.028)
Other farmer	0.034	(0.035)	(0.014)	(0.014)	(0.019)	-0.087***	0.024	0.016
	(0.023)	(0.030)	(0.024)	(0.017)	(0.025)	(0.023)	(0.023)	(0.025)
Phone/SMS	(0.017)	0.063	0.062	0.020	0.176***	(0.009)	0.002	(0.030)
	(0.048)	(0.049)	(0.056)	(0.028)	(0.060)	(0.045)	(0.047)	(0.038)
Received advice in last 12 months								
Radio	**0.085*** **	**0.048***	**-0.030**	**0.026**	**0.023**	**-0.001**	**0.064*** **	**0.019**
	(0.023)	**(0.029)**	**(0.024)**	**(0.017)**	**(0.025)**	**(0.023)**	**(0.023)**	**(0.024)**
Government	0.074***	0.008	0.010	-0.044***	-0.018	-0.034	0.059***	(0.034)
	(0.022)	(0.027)	(0.023)	(0.016)	(0.024)	(0.023)	(0.021)	(0.022)
NGO	0.069**	-0.089***	0.045	0.004	0.102***	(0.028)	0.066**	0.015
	(0.029)	(0.032)	(0.032)	(0.017)	(0.032)	(0.030)	(0.028)	(0.025)
Lead farmer	0.086**	0.011	-0.080*	(0.005)	0.007	(0.011)	0.028	0.036
	(0.042)	(0.048)	(0.044)	(0.025)	(0.044)	(0.046)	(0.040)	(0.037)
Other farmer	-0.001	(0.009)	-0.026	(0.040)	-0.073**	-0.086***	0.058*	(0.004)
	(0.032)	(0.041)	(0.034)	(0.026)	(0.034)	(0.033)	(0.031)	(0.038)
Phone/SMS	(0.068)	0.047	0.054	0.041	0.087	-0.032	(0.041)	0.036
	(0.064)	(0.063)	(0.076)	(0.040)	(0.076)	(0.056)	(0.062)	(0.055)
Household-level controls	YES	YES	YES	YES	YES	YES	YES	YES
Community-level controls	YES	YES	YES	YES	YES	YES	YES	YES
Soil type controls	YES	YES	YES	YES	YES	YES	YES	YES
Climate-related controls	YES	YES	YES	YES	YES	YES	YES	YES
N	5,172	2,961	5,172	2,840	5,172	2,961	5,172	2,113

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: NGO = nongovernmental organization; SMS = short message service. Models were estimated using xtreg command in Stata; adoption models were estimated conditional on awareness. Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 3. Effect of radio programming and other sources of agricultural information on the likelihood of technology awareness and adoption of other agricultural practices

	Water management		Crop residue incorporation		Bunds		Compost-ing	Manure making	Organic fertilizer
	Aware	Adopt	Aware	Adopt	Aware	Adopt	Aware	Aware	Adopt
Received advice in last 2 years									
Radio	**0.066*** **	**(0.036)**	**-0.042***	**0.033**	**0.051** **	**0.007**	**(0.026)**	**-0.048**	**0.101**
	(0.018)	**(0.029)**	**(0.022)**	**(0.029)**	**(0.024)**	**(0.027)**	**(0.021)**	**(0.024)**	**(0.115)**
Government	0.034**	(0.034)	0.016	0.011	0.059***	0.031	0.050**	0.014	0.261**
	(0.017)	(0.027)	(0.022)	(0.030)	(0.023)	(0.028)	(0.021)	(0.023)	(0.117)
NGO	0.064***	(0.003)	0.078***	(0.003)	0.104***	(0.008)	0.105***	0.131***	0.035
	(0.021)	(0.031)	(0.025)	(0.033)	(0.031)	(0.030)	(0.025)	(0.031)	(0.132)
Lead farmer	0.009	(0.006)	-0.071**	0.056	(0.016)	0.056	(0.040)	0.010	0.499***
	(0.031)	(0.044)	(0.033)	(0.044)	(0.043)	(0.039)	(0.033)	(0.043)	(0.174)
Other farmer	0.068***	(0.001)	0.033	0.042	0.020	0.017	0.018	0.023	0.127
	(0.025)	(0.039)	(0.024)	(0.032)	(0.033)	(0.029)	(0.023)	(0.032)	(0.128)
Phone/SMS	-0.101**	0.158*	0.170***	0.019	(0.047)	(0.064)	0.078	(0.020)	0.334
	(0.045)	(0.086)	(0.057)	(0.061)	(0.070)	(0.057)	(0.058)	(0.077)	(0.270)
Received advice in last 12 months									
Radio	**0.029***	**(0.029)**	**(0.011)**	**0.113** **	**0.006**	**0.001**	**-0.251** **	**0.099*** **	**0.089**
	(0.017)	**(0.027)**	**(0.025)**	**(0.048)**	**(0.021)**	**(0.030)**	**(0.126)**	**(0.024)**	**(0.129)**
Government	0.045***	0.012	0.039**	(0.022)	0.063***	0.038	0.073	0.096***	0.143
	(0.017)	(0.029)	(0.023)	(0.032)	(0.022)	(0.028)	(0.119)	(0.023)	(0.122)
NGO	0.060***	0.023	0.080**	0.014	0.107***	-0.075**	0.684***	0.060**	0.055
	(0.018)	(0.028)	(0.031)	(0.040)	(0.025)	(0.036)	(0.165)	(0.030)	(0.162)
Lead farmer	0.029	0.014	(0.069)	0.037	0.035	(0.029)	0.054	0.011	0.455*
	(0.023)	(0.034)	(0.043)	(0.059)	(0.032)	(0.051)	(0.228)	(0.043)	(0.233)
Other farmer	0.057***	(0.042)	(0.008)	(0.041)	0.049**	0.078*	0.119	(0.004)	0.224
	(0.018)	(0.030)	(0.034)	(0.046)	(0.024)	(0.040)	(0.170)	(0.033)	(0.177)
Phone/SMS	(0.003)	0.073	0.144*	(0.052)	0.077	(0.046)	(0.103)	(0.073)	0.287
	(0.035)	(0.049)	(0.077)	(0.083)	(0.054)	(0.075)	(0.402)	(0.067)	(0.354)

Source of raw data: IFPRI household and community surveys (2016, 2018).

Note: NGO = nongovernmental organization; SMS = short message service. Models were estimated using xtreg command in Stata, conditional on awareness. Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at *p < 0.05, **p < 0.01, ***p < 0.001.

Table 4. Effects of listening to agricultural radio programming and other delivery methods on the likelihood of awareness and adoption of crop residue incorporation

Method	Awareness	Adoption
Radio	**0.089*****	**0.106*****
	(0.021)	**(0.034)**
Farmer field day	0.071*	-0.086*
	(0.038)	(0.050)
Farm demonstration	0.075**	0.036
	(0.031)	(0.039)
Print materials	0.133**	0.036
	(0.059)	(0.066)
Mobile phone text messaging	0.069	(0.015)
	(0.052)	(0.058)
Face-to-face visits	(0.004)	(0.018)
	(0.026)	(0.033)
Community/group meeting	0.053**	0.022
	(0.022)	(0.029)
GVAC/VAC	-0.137	0.053
	(0.031)	(0.043)
Household-level controls	YES	YES
Community-level controls	YES	YES
Soil type controls	YES	YES
Climate-related controls	YES	YES
N	2,961	2,961

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: GVAC = group village agricultural committee; VAC = village agricultural committee. Models are estimated using xtreg command in Stata, conditional on awareness. Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 5. Effects of listening to agricultural radio programming on the intensity of adoption of crop residue incorporation

Variables	**FE, linear**	**RE, linear**	**CRE, linear**	**CRE, fractional**
Radio	**0.041**	**0.051*** **	**0.084*** **	**0.086*** **
	(0.032)	**(0.017)**	**(0.025)**	**(0.027)**
Farmer field day	-0.092*	-0.040	-0.091**	-0.087**
	(0.052)	(0.028)	(0.042)	(0.046)
Farm demonstration	-0.007	0.047*	0.039	0.037
	(0.044)	(0.024)	(0.035)	(0.038)
Print materials	0.020	0.038	0.006	0.004
	(0.069)	(0.040)	(0.058)	(0.063)
Mobile phone text messaging	0.040	0.019	0.012	0.012
	(0.063)	(0.035)	(0.052)	(0.056)
Face-to-face visits	-0.035	-0.018	-0.027	(0.027)
	(0.038)	(0.020)	(0.030)	(0.033)
Community/group meeting	0.033	0.036**	0.034	0.035
	(0.033)	(0.017)	(0.026)	(0.028)
GVAC/VAC	0.060	-0.018	0.045	0.044
	(0.049)	(0.025)	(0.037)	(0.041)
Household controls	YES	YES	YES	YES
Community controls	YES	YES	YES	YES
Soil type controls	YES	YES	YES	YES
Climate-related controls	YES	YES	YES	YES
N	2,961	2,961	2,961	2,961

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: FE = fixed effects; RE = random effects; CRE = correlated random effects; GVAC = group village agricultural committee; VAC = village agricultural committee. Models 1 through 3 were estimated using xtreg command in Stata, conditional on awareness. Model 4 was estimated using generalized estimating equation (GEE) xtgee for fractional response, conditional on awareness (included only those who were aware of the specific technology). Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 6. Effects of listening to radio programming and other sources of agricultural information on crop diversification

Source of extension advice (reference = no receipt)	Marginal effects of extension advice received from [SOURCE] in last 2 years on crop diversification				Marginal effects of extension advice received from [SOURCE] in the last 12 months on crop diversification			
	FE, linear	RE, linear	CRE, linear	CRE, fractional	FE, linear	RE, linear	CRE, linear	CRE, fractional
Radio	**0.010**	**0.009**	**0.013**	**0.010**	**0.009**	**0.016****	**0.009**	**0.010**
	(0.009)	**(0.007)**	**(0.009)**	**(0.020)**	**(0.010)**	**(0.007)**	**(0.010)**	**(0.026)**
Government	0.002	0.011*	0.004	0.008	-0.004	0.010	-0.003	-0.002
	(0.009)	(0.007)	(0.009)	(0.021)	(0.009)	(0.007)	(0.009)	(0.025)
NGO	0.001	0.010	-0.001	0.001	-0.010	0.001	-0.008	-0.008
	(0.010)	(0.007)	(0.010)	(0.023)	(0.012)	(0.009)	(0.012)	(0.033)
Lead farmer	0.015	0.001	0.015	0.024	0.023	0.001	0.017	0.016
	(0.013)	(0.010)	(0.013)	(0.030)	(0.017)	(0.013)	(0.017)	(0.047)
Other farmer	-0.004	-0.009	-0.007	(0.014)	0.007	-0.004	0.011	0.011
	(0.010)	(0.007)	(0.010)	(0.022)	(0.014)	(0.010)	(0.013)	(0.036)
Phone/SMS	-0.006	0.004	-0.015	(0.013)	-0.046*	-0.028	-0.047*	-0.047
	(0.020)	(0.015)	(0.020)	(0.046)	(0.027)	(0.021)	(0.026)	(0.072)

Source of raw data: IFPRI household and community surveys (2016, 2018).

Note: FE = fixed effects; RE = random effects; CRE = correlated random effects; NGO = nongovernmental organization; SMS = short message service. Models 1 through 3 and 5 through 7 were estimated using xtreg command in Stata, conditional on awareness. Models 4 and 8 were estimated using generalized estimating equation (GEE) xtgee for fractional response, conditional on awareness. Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

Table 7. Effects of listening to radio programming and other delivery methods of agricultural information on crop diversification

Method	FE, linear	RE, linear	CRE, linear	CRE, fractional
Radio	**0.016***	**0.022*****	**0.019****	**0.021**
	(0.009)	**(0.006)**	**(0.008)**	**(0.023)**
Farmer field day	0.026*	0.014	0.021	0.019
	(0.015)	(0.011)	(0.014)	(0.039)
Farm demo	-0.009	0.006	-0.005	(0.003)
	(0.012)	(0.009)	(0.012)	(0.033)
Print materials	0.015	-0.005	0.014	0.015
	(0.021)	(0.017)	(0.021)	(0.057)
SMS/phone	-0.013	-0.010	-0.023	(0.026)
	(0.019)	(0.015)	(0.019)	(0.051)
Face-to-face visits	-0.019*	-0.005	-0.019*	(0.019)
	(0.010)	(0.008)	(0.010)	(0.027)
Community/group meeting	0.005	0.012*	0.004	0.003
	(0.009)	(0.007)	(0.009)	(0.023)
GVAC/VAC	0.003	0.003	-0.001	(0.003)
	(0.013)	(0.010)	(0.012)	(0.033)

Source of raw data: IFPRI household and community surveys (2016, 2018).

Note: FE = fixed effects, RE = random effects, CRE = correlated random effects; SMS = short message service; GVAC = group village agricultural committee; VAC = village agricultural committee. Models 1 through 3 were estimated using xtreg command in Stata, conditional on awareness. Model 4 was estimated using generalized estimating equation (GEE) xtgee for fractional response, conditional on awareness (included only those who were aware of the specific technology). Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 8. Effects of listening to radio programming and other sources of agricultural information on legume acreage

Method	Marginal effects of extension advice received through [METHOD] on % of crop cultivated with legumes				Marginal effects of extension advice received through [METHOD] on crop acreage with legumes		
	FE, linear	RE, linear	CRE, linear	CRE, fractional	FE, linear	RE, linear	CRE, linear
Radio	**-0.004**	**0.012****	**-0.004**	**0.006**	**-0.035**	**0.005**	**-0.033**
	(0.008)	**(0.006)**	**(0.008)**	**(0.015)**	**(0.027)**	**(0.020)**	**(0.027)**
Farmer field day	0.019	0.014	0.019	0.021	0.104**	0.130***	0.101**
	(0.013)	(0.010)	(0.013)	(0.027)	(0.046)	(0.036)	(0.046)
Farm demonstration	0.008	0.012	0.007	(0.000)	-0.006	-0.021	-0.004
	(0.011)	(0.009)	(0.011)	(0.022)	(0.038)	(0.030)	(0.038)
Print materials	0.012	0.001	0.007	0.004	0.105	0.074	0.079
	(0.019)	(0.016)	(0.019)	(0.038)	(0.067)	(0.054)	(0.067)
SMS/phone	-0.006	0.016	-0.010	(0.005)	0.043	0.148***	0.028
	(0.017)	(0.013)	(0.017)	(0.033)	(0.059)	(0.046)	(0.059)
Face-to-face visits	0.004	0.007	0.004	0.006	0.041	0.032	0.041
	(0.009)	(0.007)	(0.009)	(0.019)	(0.032)	(0.025)	(0.032)
Community/group meeting	0.007	0.004	0.009	0.014	0.019	0.009	0.016
	(0.008)	(0.006)	(0.008)	(0.016)	(0.028)	(0.021)	(0.027)
GVAC/VAC	-0.016	-0.016*	-0.018	(0.019)	0.008	0.023	0.007
	(0.012)	(0.009)	(0.011)	(0.023)	(0.040)	(0.030)	(0.039)

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: FE = fixed effects; RE = random effects; CRE = correlated random effects; SMS = short message service; GVAC = group village agricultural committee; VAC = village agricultural committee. Models 1 through 3 and 5 through 7 were estimated using xtreg command in Stata, conditional on awareness. Models 4 and 8 were estimated using generalized estimating equation (GEE) xtgee for fractional response, conditional on awareness (included only those who were aware of the specific technology). Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 9. Effects of listening to radio programming and other delivery methods on legume acreage

Source of extension advice (reference = no receipt)	**Marginal effects of extension advice received through [METHOD] on % of crop cultivated with legumes**				**Marginal effects of extension advice received through [METHOD] on crop acreage with legumes**		
	FE, linear	**RE, linear**	**CRE, linear**	**CRE, fractional**	**FE, linear**	**RE, linear**	**CRE, linear**
Received advice in the last 2 years							
Radio	**0.036**	**0.069*** **	**0.042**	**0.002**	**-0.000**	**0.010***	**0.003**
	(0.028)	**(0.021)**	**(0.027)**	**(0.016)**	**(0.008)**	**(0.006)**	**(0.008)**
Government	-0.005	0.021	0.002	0.004	-0.000	0.008	0.000
	(0.029)	(0.021)	(0.028)	(0.017)	(0.008)	(0.006)	(0.008)
NGO	-0.024	-0.015	-0.020	(0.006)	-0.016*	-0.007	-0.015*
	(0.032)	(0.024)	(0.031)	(0.018)	(0.009)	(0.007)	(0.009)
Lead farmer	-0.021	-0.022	-0.025	(0.001)	-0.006	-0.013	-0.007
	(0.041)	(0.032)	(0.041)	(0.024)	(0.012)	(0.009)	(0.012)
Other farmer	-0.008	0.004	-0.014	0.007	0.007	0.012*	0.005
	(0.031)	(0.024)	(0.030)	(0.018)	(0.009)	(0.007)	(0.009)
Phone/SMS	0.048	0.101**	0.038	0.002	-0.006	0.009	-0.008
	(0.063)	(0.049)	(0.063)	(0.036)	(0.018)	(0.014)	(0.018)
Received advice in the last 12 months							
Radio	**0.005**	**0.018*** **	**0.006**	**0.008**	**0.017**	**0.063*** **	**0.021**
	(0.009)	**(0.007)**	**(0.009)**	**(0.018)**	**(0.031)**	**(0.023)**	**(0.031)**
Government	0.005	0.009	0.005	0.006	0.033	0.049**	0.039
	(0.009)	(0.006)	(0.009)	(0.017)	(0.030)	(0.022)	(0.029)
NGO	-0.005	-0.005	-0.002	0.005	-0.011	-0.006	0.002
	(0.011)	(0.008)	(0.011)	(0.022)	(0.039)	(0.029)	(0.038)
Lead farmer	-0.021	-0.025**	-0.018	(0.012)	-0.071	-0.059	-0.064
	(0.016)	(0.012)	(0.016)	(0.032)	(0.055)	(0.042)	(0.054)
Other farmer	0.007	0.012	0.004	0.005	0.029	0.031	0.021
	(0.012)	(0.009)	(0.012)	(0.024)	(0.042)	(0.033)	(0.042)
Phone/SMS	-0.028	0.000	-0.025	(0.021)	-0.071	0.030	-0.065
	(0.024)	(0.019)	(0.024)	(0.047)	(0.084)	(0.067)	(0.084)

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: FE = fixed effects, RE = random effects, CRE = correlated random effects; NGO = nongovernmental organization; SMS = short message service. Models 1 through 3 and 5 through 7 were estimated using xtreg command in Stata, conditional on awareness. Model 4 was estimated using generalized estimating equation (GEE) xtgee for fractional response, conditional on awareness (included only those who were aware of the specific technology). Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

Table 10. Effects of listening to radio programming and other sources of agricultural information on household dietary diversity

Source of extension advice (reference = no receipt)	Marginal effects of extension advice received from [SOURCE] in last 12 months on dietary diversity			Marginal effects of extension advice received from [SOURCE] in last 2 years on dietary diversity		
	FE, linear	RE, linear	CRE, linear	FE, linear	RE, linear	CRE, linear
Radio	**0.248***** **(0.087)**	**0.332***** **(0.059)**	**0.222***** **(0.083)**	**0.209**** **(0.097)**	**0.236***** **(0.066)**	**0.180*** **(0.093)**
Government	0.207** (0.089)	0.229*** (0.059)	0.225*** (0.085)	0.378*** (0.092)	0.355*** (0.063)	0.397*** (0.089)
NGO	0.143 (0.099)	0.286*** (0.067)	0.171* (0.095)	0.346*** (0.121)	0.347*** (0.082)	0.358*** (0.116)
Lead farmer	-0.007 (0.127)	-0.116 (0.090)	-0.057 (0.123)	0.061 (0.169)	-0.121 (0.119)	0.099 (0.164)
Other farmer	-0.024 (0.096)	-0.042 (0.068)	-0.006 (0.092)	-0.007 (0.132)	0.057 (0.093)	0.030 (0.127)
Phone/SMS	0.166 (0.198)	0.363*** (0.139)	0.187 (0.192)	-0.193 (0.265)	0.081 (0.191)	-0.027 (0.255)

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: FE = fixed effects, RE = random effects, CRE = correlated random effects; NGO = nongovernmental organization; SMS = short message service. Models were estimated using xtreg command in Stata, conditional on awareness. Alternatively, xtpoisson was also used and the results are largely consistent. Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

Table 11. Effects of listening to radio programming and other delivery methods on household dietary diversity

Method	FE, linear	RE, linear	CRE, linear
Radio	**0.256***** **(0.083)**	**0.349***** **(0.058)**	**0.205**** **(0.080)**
Farmer field day	0.029 (0.143)	0.073 (0.101)	0.097 (0.138)
Farm/cooking demonstration	0.338*** (0.119)	0.264*** (0.085)	0.294** (0.115)
Print materials	0.453** (0.208)	0.424*** (0.153)	0.424** (0.202)
SMS/phone	0.018 (0.184)	0.288** (0.131)	0.049 (0.178)
Face-to-face visits	0.059 (0.100)	0.136* (0.071)	0.045 (0.097)
Community/group meeting	0.279*** (0.086)	0.341*** (0.060)	0.340*** (0.082)
GVAC/VAC	0.082 (0.123)	0.003 (0.085)	-0.000 (0.117)

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: FE=fixed effects, RE = random effects, CRE = correlated random effects; SMS = short message service; GVAC = group village agricultural committee; VAC = village agricultural committee. Models were estimated using xtreg command in Stata, conditional on awareness (included only those who were aware of the specific technology). Alternatively, xtpoisson was used and the results were largely consistent. Figures are the marginal effects, and those in parentheses are the standard errors. Various household-level, community-level, soil type, and climate-related variables were used as controls in the models; see their descriptive statistics in Table A1. Significant at $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

5.2. Gender of the Receiver of Information

We estimated similar models as above but this time we included the gender of the listener(s) or receiver(s) of information. Our results show that for many of the outcome variables, the receiver's gender and the method of receiving information matters (Table 12). For organic fertilizer adoption, a male receiving information from community/group meetings and a female receiving information from radio increases the intensity of the household's adoption by a total of 8 percent. For bunds, a male receiving information from radio and community/group meetings and a female receiving information from radio and printed materials increases the intensity of the household's adoption by a total of 36 percent. However, a female receiver of information from face-to-face visits seems to have reduced the intensity of adoption of bunds. For crop residue incorporation adoption, a male and a female receiving information from radio increases the intensity of the household's adoption by a total of 14 percent. For minimum tillage, a male receiving information from community/group meetings reduces the intensity of adoption, while a female receiving information from a GVAC/VAC increases the intensity of adoption by 4 percent. A male receiving information from farmer field days increases legume acreage and the percentage of crop acreage to legumes, while a female receiving advice from a GAC/VAC reduces the percentage of legume acreage. A male receiving advice from radio and community/group visits increases the household dietary diversity score by 0.37 and 0.30 score points, respectively; and a female receiving advice from farm/cooking demonstrations and community/group meetings increases the household dietary diversity score by 0.37 and 22 score points, respectively.

Table 12. Effect of gender of the receiver of information on outcome indicators

	Organic fertilizer	Bunds	Crop residue incor-poration	Minimum tillage	Legume acreage	% of crop acreage to legume	HDDS
Male in the household used …							
Farmer field day	(0.016)	0.038	-0.110*	0.000	0.158***	0.030*	0.012
	(0.041)	(0.042)	(0.058)	(0.021)	(0.059)	(0.017)	(0.182)
Farm demonstration	(0.000)	0.011	0.026	0.025	-0.041	-0.002	0.177
	(0.033)	(0.034)	(0.047)	(0.018)	(0.048)	(0.014)	(0.148)
Print materials	0.010	0.027	0.011	(0.002)	0.024	0.002	0.358
	(0.057)	(0.059)	(0.075)	(0.027)	(0.080)	(0.023)	(0.250)
Radio	(0.003)	0.037*	0.083***	0.007	(0.004)	0.003	0.369***
	(0.022)	(0.022)	(0.031)	(0.014)	(0.031)	(0.009)	(0.096)
SMS/phone	0.051	0.020	(0.032)	(0.017)	0.057	(0.004)	0.264
	(0.049)	(0.050)	(0.066)	(0.026)	(0.069)	(0.020)	(0.214)
Face-to-face visits	0.001	(0.042)	(0.006)	(0.001)	0.071*	0.003	0.007
	(0.028)	(0.029)	(0.040)	(0.016)	(0.040)	(0.012)	(0.125)
Community/group meeting	0.042*	0.086***	0.029	-0.028*	(0.009)	0.010	0.302***
	(0.023)	(0.024)	(0.034)	(0.015)	(0.034)	(0.010)	(0.104)
GVAC/VAC	0.002	(0.013)	0.031	(0.002)	(0.031)	(0.011)	0.000
	(0.033)	(0.035)	(0.050)	(0.018)	(0.048)	(0.014)	(0.149)
Female in the household used …							
Farmer field day	(0.043)	(0.025)	(0.000)	0.002	0.055	0.005	0.223
	(0.046)	(0.049)	(0.068)	(0.026)	(0.067)	(0.019)	(0.208)
Farm/cooking demonstration	0.056	0.028	0.014	(0.008)	0.059	0.018	0.367**
	(0.036)	(0.037)	(0.051)	(0.020)	(0.052)	(0.015)	(0.160)
Print materials	(0.075)	0.176**	(0.115)	(0.030)	0.084	(0.000)	0.304
	(0.076)	(0.082)	(0.113)	(0.043)	(0.109)	(0.032)	(0.341)
Radio	0.044*	0.060***	0.053*	0.003	(0.008)	0.001	0.131
	(0.023)	(0.024)	(0.033)	(0.014)	(0.032)	(0.009)	(0.100)
SMS/phone	0.018	(0.098)	0.096	0.005	0.091	0.024	(0.486)
	(0.071)	(0.071)	(0.097)	(0.036)	(0.101)	(0.029)	(0.312)
Face-to-face visits	0.037	-0.073**	(0.040)	(0.023)	0.001	0.003	0.052
	(0.028)	(0.030)	(0.040)	(0.018)	(0.040)	(0.012)	(0.124)
Community/group meeting	(0.031)	(0.025)	(0.006)	(0.002)	0.046	0.007	0.216**
	(0.023)	(0.23)	(0.034)	(0.015)	(0.032)	(0.009)	(0.100)
GVAC/VAC	0.048	0.015	0.042	0.043**	0.005	-0.031**	(0.257)
	(0.035)	(0.039)	(0.059)	(0.021)	(0.052)	(0.015)	(0.162)

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: HDDS = household dietary diversity score; SMS = short message service; GVAC = group village agricultural committee; VAC = village agricultural committee. Significant at **p* < 0.05, ***p* < 0.01, ****p* < 0.001.

5.3. Women's Empowerment

Listening to radio programming is strongly associated with greater empowerment for women and men by three to five score points (Table 13). The effect is higher for women: four to six greater score points for women compared with three to four greater score points for men. In a qualitative study, Mudege et al. (2015) found that women's access to knowledge and collective action improved their empowerment in Malawi. However, we do not see an association between female or male access to radio programming and greater gender parity at the household level (Table 14).

Table 13. Average treatment effects of radio programming on empowerment scores, from various matching techniques

	Stratification		Kernel		Nearest Neighbor		IPTW	
Received information from radio in the last 2 years (= 1) versus did not receive (= 0)								
All	0.034	***	0.039	***	0.032	***	0.033	***
	(0.007)		(0.006)		(0.008)		(0.007)	
Female	0.036	***	0.037	***	0.037	***	0.035	***
	(0.011)		(0.011)		(0.011)		(0.010)	
Male	0.028	***	0.029	***	0.028	***	0.030	***
	(0.010)		(0.010)		(0.011)		(0.009)	
Received information from radio in the 12 months (= 1) versus did not receive (= 0)								
All	0.050	***	0.050	***	0.051	***	0.049	***
	(0.008)		(0.008)		(0.008)		(0.007)	
Female	0.062	***	0.059	***	0.056	***	0.055	***
	(0.009)		(0.010)		(0.011)		(0.010)	
Male	0.040	***	0.040	***	0.042	***	0.041	***
	(0.008)		(0.009)		(0.010)		(0.008)	
Used radio programming for agricultural and nutrition advice (= 1)								
All	0.046	***	0.045	***	0.046	***	0.044	***
	(0.007)		(0.007)		(0.008)		(0.007)	
Female	0.045	***	0.044	***	0.044	***	0.045	***
	(0.009)		(0.010)		(0.011)		(0.009)	
Male	0.045	***	0.045	***	0.045	***	0.043	***
	(0.010)		(0.010)		(0.010)		(0.009)	

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: IPTW = inverse probability of treatment weighting. Significant at *p < 0.05, **p < 0.01, ***p < 0.001.

Table 14. Effects of radio programming on intrahousehold gender parity

Source of extension advice (reference = no receipt)	Marginal effect of radio access in last 12 months on gender parity	Marginal effect of radio access in last 2 years on gender parity
Radio	**0.002**	**0.002**
	(0.016)	**(0.017)**
Government	0.004	0.005
	(0.017)	(0.017)
NGO	(0.006)	(0.005)
	(0.018)	(0.018)
Lead farmer	(0.001)	(0.001)
	(0.024)	(0.024)
Other farmer	0.007	0.006
	(0.018)	(0.017)
Phone/SMS	0.002	0.002
	(0.036)	(0.035)

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: NGO = nongovernmental organization; SMS = short message service. Significant at *p < 0.05, **p < 0.01, ***p < 0.001.

6. DISCUSSION

6.1. Contribution of Radio Programming

As we saw in Figures 6 and 7 earlier in the paper, radio is the top method of agricultural and nutrition advice. In the IFPRI household surveys (2016, 2018), 60 percent of households reported listening to radio at least once a week and 41 percent listened at least once daily. More than half of women (52 percent) reported listening to radio at least once a week. Those results highlight the crucial role radio performs in providing information to rural women, who historically have less access to extension services than rural men.

Compared with other sources, radio is the first or second major source and delivery method of conveying agricultural and nutrition information to rural communities. In terms of source of agricultural information, radio is next to government agricultural extension workers in terms of coverage (based on survey data) and in terms of relevance (based on the FGDs). In terms of source of nutrition information, radio is next to health surveillance assistants in terms of coverage (based on survey data) and relevance (based on the FGDs). In terms of information on climate change and climate-smart agricultural practices, radio programming is the main source and delivery method of information. Based on the FGDs, the radio is considered an important source of information because farmers can learn what other different areas are doing in terms of farming. It also gives an opportunity to people who are not part of a group to get agricultural information as some NGOs, lead farmers, and government extension workers target people in groups. Information on the radio is in the form of a discussion, which makes it interesting to listen while learning. Information via radio can be accessed daily or weekly and one can listen while performing other tasks or during rest or relaxation times.

Listening to radio programming has a strong positive effect on the awareness and knowledge of most of the climate-smart agricultural practices being promoted. Conditional on awareness and exposure, we see a strong positive effect of listening to or receiving agricultural information from radio programming in the last 12 months on the likelihood and the intensity of adoption of crop residue incorporation. However, we do not see any effect of radio programming or any other sources or methods of information delivery on all other practices. This means that it takes more than just information to influence adoption of most of the technologies being promoted. We need to understand how we can make extension services and information provision more iterative and engaging and more effective.

We also did not see a consistently positive impact from radio program listening on crop diversification or legume harvested area, but we do see a consistently positive impact from access to radio programming on improved household dietary diversity scores. Radio programming may not have influenced acreage or cropping patterns based on existing acreage, but it may have improved production/harvest levels, which may have enabled households to either sell more and buy more diverse and nutritious foods or keep more produce for their own home food consumption.

Another contribution of radio messaging is market information, which farmers cannot access as easily as agricultural or nutrition information. This is confirmed by the household surveys and FGDs. Farmers' primary source of market information is the radio. The radio acts as an important source of market information because farmers can learn about prices in other areas even if they may not be able to access such markets. Government extension workers are a second important source of market information. Extension workers encourage the farmers to form cooperatives through which they can easily find a market for their produce. Vendors or traders are also sources of market and price information. In addition, farmers get market information via mobile phones; this is fast but as with the other sources, such markets are not accessible to the farmers.

6.2. What Extension Sources and Delivery Methods Are Most Effective?

We combine various data and summarize the sources' and methods' effectiveness based on a set of criteria, including national coverage (Figures 6 and 7), farmers' perception of their usefulness and relevance (from survey data and FGDs), effect on technology awareness (Tables 2 through 5), and effect on technology adoption (Tables 2 through 5). Government and NGO extension services and radio messaging to farmers have the most coverage, are considered the most useful and relevant, and also make the strongest contribution to greater awareness of most technologies being promoted (Table 15). Ideally, combining these three would yield the greater effect on technology awareness, but in areas where government and NGO extension workers are not available, radio programming can be a cost-effective tool for wider promotion of climate-smart agricultural practices. As traditional extension services are either very expensive or not accessible, new and more efficient models of innovation delivery have to be sought and implemented on a wider scale. Such new delivery models should build on existing community-level social structures and networks to induce greater and faster diffusion. Moreover, to reduce outreach costs, we can potentially make better use of modern information and communication tools, particularly radio, to induce broad-based awareness and exposure.

Table 15. Indications of and comparison of effectiveness of different extension sources, based on various indicators of "effectiveness"

Source	Coverage (HH survey)[a]	Usefulness (HH survey)[b]	Usefulness (FGD)[c]	Technology awareness (HH survey)[d]	Technology adoption (HH survey)[d]	Crop diversification (HH survey)[e]	Legume acreage[f]	HDDS[g]
Radio	*****	****	****	****	*	*		***
Government extension	*****	****	******	****	*			***
NGO extension	***	****	***	******				***
Other farmer	**	***		**	***			
Lead farmer	*	****	**	*	*			
Mobile phone/SMS	*	****		*				
Private sector	*	***						

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: A greater number of stars means greater effectiveness and a greater statistical effect on agricultural and development outcomes. HH = household; FGD = focus group discussion; HDDS = household dietary diversity score; NGO = nongovernmental organization; SMS = short messaging service.
[a] Based on Figures 6 and 7.
[b] Based on household survey, in which most households rated all sources of extension services favorably.
[c] Based on first section in the discussion.
[d] Based on Tables 2 and 5.
[e] Based on Tables 6 and 7.
[f] Based on Tables 8 and 9.
[g] Based on Tables 10 and 11.

Chapota, Fatch, and Mthinda (2014) noted that radio programs led to the adoption of new farming practices by an average of 20 percent of households living in passive listening communities in Malawi. Although those authors did not specify the new farming practices, our results show that radio extension seems to help in promoting adoption of crop diversification and intensity of adoption of crop residue incorporation only, but not all other technologies (Tables 2 through 5). These results perhaps suggest that radio can help in promoting adoption of simple technologies or practices such as crop diversification and crop residue incorporation as opposed to technologies that would be seen as complex or too technical. Across the different technologies, other farmers seem to be the source that can induce the greatest impact on adoption. In terms of delivery methods, farm demonstrations, farmer field days, print materials, and community/group meetings help in the intensity of adoption as they appear significant and positive in a few models although not consistently in all estimation models (Table 16). Overall, we see no effect of extension services regardless of the source and delivery method in terms of adoption of most technologies being promoted. This indicates the need to look seriously at how such information is being delivered to induce behavioral change among farmers. The FGDs reveal a lack of deep understanding of the technologies being promoted.

Table 16. Indications of and comparison of the effectiveness of different extension delivery methods, based on various indicators of "effectiveness"

Method	Coverage (HH survey)[a]	Useful-ness (HH survey)[b]	Useful-ness (FGD)[c]	Technology awareness (HH survey)[d]	Technology adoption (HH survey)[d]	Crop diver-sification (HH survey)[e]	Legume acreage[f]	HDDS[g]
Radio	******	****	*****	**	**	**		***
Community/group meetings	******	****	***	**	*			***
Face-to-face visits	****	****	*****	***	*			
Farm/cooking demo	***	****	*****	*	*			***
Lead farmer	***	****	*					
VAC/VDC	**	****		*	*			
Farmer field day	**	****		*	*		*	
Printed materials	*	****		***	*			***

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: A greater number of stars indicates greater effectiveness and a greater statistical effect on awareness of or adoption of the technology. HH = household; FGD = focus group discussion; HDDS = household dietary diversity score; VAC = village agricultural committee; VDC = village development committee.
[a] Based on Figures 6 and 7
[b] Based on the household survey, in which most households rated all delivery methods favorably.
[c] Based on first section in the discussion.
[d] Based on Tables 2 and 5.
[e] Based on Tables 6 and 7.
[f] Based on Tables 8 and 9.
[g] Based on Tables 10 and 11.

6.3. Relationship between Radio Messaging Access and Women's Empowerment

Younger women and men used radio more than other sources for their agricultural information needs. Younger and older men used radio more than other sources for nutrition education. Radio seems to be a critical delivery platform for nutrition education for men, circumventing strong gender norms that traditionally put domestic work and nutrition within the woman's domain while men are usually teased and laughed at when attending meetings or trainings related to nutrition (see Ragasa, Aberman, and Alvarez-Mingote 2019).

Our results also show that interactive radio programming has a significant effect on both women's and men's empowerment scores. Access to radio programming is associated with greater empowerment for women and men by three to five score points. Relative to other sources, access to radio had a greater effect on women's empowerment than on men's—a four to six score point increase for women versus a three to four score point increase for men. Mechanisms for this gendered outcome include radio easing women's time burden (since they can listen to programming while working and without having to attend trainings) as well as awareness campaigns and messages addressing gender equality. Consider the following comments drawn from the FGDs:

> "On gender, we learnt that there shouldn't be any difference between man and woman in terms of work they do, e.g., when a woman is tired, a man can help."
>
> —Participant in a female FGD, Chitseko community

> "On gender, we have heard on the radio that men and women are supposed to be given equal opportunities."
>
> —Participant in a female FGD, Junju community

A total of 60 percent of households achieved intrahousehold gender parity (that is, the woman is at least as empowered as the male respondent in the household). We did not see an effect of access to radio programming on intrahousehold gender parity scores, and almost all of the explanatory variables were not statistically significant in explaining variations in gender parity. Men's access to nutrition advice via radio reduces the gap between women's and men's empowerment scores.

6.4. Contribution of Listening Clubs and Mobile Platforms

With respect to listening clubs and mobile platforms, we saw no statistical difference in effect between villages in treatment districts and those in control districts. For Malawi, these results are important in terms of what mobile-based extension can do because previous findings have demonstrated the impact of mobile platforms only on access to agricultural, nutrition, and market information, and not on adoption of climate-smart or other management practices (Chisama 2016; Katengeza, Okello, and Jambo 2011). Elsewhere, findings from randomized experiments showed that mobile platforms improved agricultural output, household income, and diversification of crops, particularly marginal cash crops grown by women (Aker and Ksoll 2016; Musafiri 2016). These results argue for promoting awareness among farmers regarding use of these ICT-based approaches or platforms; but perhaps most importantly, messages should be kept simple as opposed to complex or technical for farmers to easily take up and act on the advice.

Listening clubs linked to radio programs may be useful platforms that strengthen social capital and cooperation among listeners, based on the FGDs; however, we do not see differences in effects between treatment districts and control districts. Call centers and mobile platforms enabling anyone to call or text for free have been thought of as very useful and responsive to users' questions and needs, but such services are still not widespread and haven't attracted many users. Again, this argues for intensified promotion of and sensitization to these services.

6.5. Demand-Driven Interactive Radio Programming

Radio programming has been demand driven at the group and community levels. At the national level, there is a yearly (at least) review and harmonization of agricultural radio messaging. Farmers choose which agricultural radio stations to listen to; they select certain stations because the issues discussed are relevant to their needs. Farmers value the following types of content the most in agricultural radio programs:

- Interviews with farmers
- Experts talking
- Experts answering questions
- Farmers answering questions
- Agricultural news
- Drama, music
- Weather forecasts
- Market prices

However, the volume of calls made to call centers is low even though the calls are free. Of the FGDs conducted, only a few focus groups knew about the opportunity to call in or text for free to ask questions or receive extension services. It seems that the promotion of such a platform is still limited and can be further intensified.

6.6. Areas for Improvement

Although radio can be a cost-effective tool for mass awareness campaigns and information "buzzing," more effort is necessary to induce behavioral change toward greater adoption of the major practices being promoted. A few strategies could improve the impact of radio programming. First, combining radio with other sources and methods would be most useful. Other sources of advice (such as government and NGO extension) affect the outcome variables, and therefore combining radio messaging and other sources matters. This is consistent with Beaman et al. (2015), who note that technology diffusion and behavior change are characterized by a complex learning environment in which most farmers need to learn from multiple people and sources before they adopt themselves.

7. CONCLUSIONS

This study assesses the effect of interactive radio programming on women's empowerment and agricultural development using a unique nationally representative household panel dataset on Malawi (2016, 2018) combined with gender-disaggregated focus group discussions and interviews of service providers. Our results affirm some anecdotal evidence and, with our rigorously collected evidence at the national level, present some surprising findings. First, our findings affirm the wide coverage and the positive contributions of radio programming nationwide. Radio is the primary method of receiving agricultural and nutrition advice. Second, by disaggregating by gender and age, we see some surprising trends: younger women and men used radio more than other sources for their agricultural information needs, while younger and older men used radio more than other sources for nutrition education. Radio seems to be a critical delivery platform for nutrition education for men; this seemingly contradicts strong gender norms regarding women's roles in domestic work and nutrition and is in spite of the fact that men can be teased or ridiculed for attending nutrition-related trainings.

Third, the study provides rigorous evidence of radio programming's strong positive role in technology awareness but its limited impact on actual adoption. Listening to radio programming has a strong positive effect on the listener's awareness of and knowledge of most of the climate-smart agricultural practices being promoted. There are consistently strong effects of receiving agricultural and nutrition information from radio programming on dietary diversity and crop residue incorporation adoption. However, we consistently see no effect from receiving agricultural and nutrition information from radio programming on legume acreage, crop diversification, or other climate-smart agricultural technologies being promoted.

Fourth, our results show a strong association between access to interactive radio programming and women's and men's empowerment scores; the association is greater with women's empowerment and younger men's empowerment, the latter being the most disempowered in the sample. The mechanisms for this gendered outcome are a lower time burden (compared with the time consumed by attending trainings or meetings, women can listen to the radio and learn while simultaneously doing their other work) and the awareness campaigns and messages on gender equality, which influenced both male and female listeners, therefore leading to changes in attitude and behavior.

Fifth, based on the national survey, only a few households belong to listening clubs or ICT hubs (2 percent) or have used the call-in services (1 percent). However, listening clubs and ICT hubs were perceived by FGD participants as useful platforms that strengthened social capital and cooperation among listeners. Moreover, call centers and mobile apps, which enable anyone to call in or text for free, also helped those who used such services. Greater community awareness about these available platforms and services will be crucial so that more people can benefit from them.

Appendix

Table A1 Descriptive statistics of variables used in the estimation models

Variable	Definition	2016 (*N* = 2,938)		2018 (*N* = 2,771)	
		Mean	**Std. Dev.**	**Mean**	**Std. Dev.**
Outcome variables					
Awareness (= 1)	Any one of the household primary decision makers is aware of or knowledgeable of [the practice]				
Soil cover		0.34	0.47	0.50	0.50
Minimum tillage		0.50	0.50	0.59	0.49
Intercropping		0.47	0.50	0.69	0.46
Crop residue incorporation		0.52	0.50	0.69	0.46
Water management		0.13	0.34	0.32	0.47
Pit planting		0.33	0.47	0.50	0.50
Bunds		0.47	0.50	0.78	0.41
Composting pits		0.55	0.50	0.76	0.43
Manure or fertilizer making		0.44	0.50	0.40	0.49
Adoption (= 1)	Any one of the household primary decision makers adopts [the practice] on his or her farm				
Soil cover		0.16	0.37	0.12	0.32
Minimum tillage		0.07	0.25	0.06	0.24
Intercropping		0.63	0.48	0.83	0.37
Crop residue incorporation		0.29	0.45	0.41	0.49
Water management		0.02	0.13	0.07	0.25
Pit planting		0.08	0.28	0.06	0.24
Bunds		0.21	0.41	0.48	0.50
Organic fertilizer		0.45	0.50	0.54	0.50
Intensity of adoption (%)	% of total crop acreage				
Soil cover		0.12	0.30	0.08	0.24
Minimum tillage		0.04	0.18	0.04	0.16
Intercropping		0.49	0.44	0.58	0.41
Crop residue incorporation		0.24	0.40	0.31	0.42
Water management		0.01	0.09	0.05	0.19
Pit planting		0.06	0.21	0.04	0.18
Bunds		0.40	0.46	0.17	0.35
Organic fertilizer		0.32	0.41	0.37	0.41
Crop diversification	Simpson index of crop diversification	0.44	0.24	0.46	0.20
Crop acreage planted with legumes		0.58	0.83	0.58	0.83
% of crop acreage planted with legumes		0.23	0.21	0.26	0.21
Household dietary diversity score		4.82	2.15	5.60	1.84
Extension-related variables					
Received agricultural advice in the last 2 years (= 1)	Any one of the household primary decision makers received extension advice in the last 2 years prior to survey	0.75	0.43	0.76	0.43
Government extension		0.49	0.50	0.54	0.50
NGO extension officers		0.21	0.40	0.28	0.45
Lead farmers		0.09	0.29	0.13	0.34
Other farmers		0.20	0.40	0.24	0.42
Radio programming		0.39	0.49	0.39	0.49
Phone/SMS		0.03	0.17	0.05	0.22

Variable	Definition	2016 (*N* = 2,938)		2018 (*N* = 2,771)	
		Mean	Std. Dev.	Mean	Std. Dev.
Received agricultural advice in the last 12 months (= 1)	Any one of the household primary decision makers received advice in the last 12 months prior to survey	0.54	0.50	0.54	0.50
Government extension		0.34	0.47	0.35	0.48
NGO extension officers		0.12	0.33	0.16	0.37
Lead farmers		0.04	0.20	0.07	0.25
Other farmers		0.09	0.29	0.11	0.31
Radio programming		0.26	0.44	0.26	0.44
Phone/SMS		0.02	0.13	0.02	0.15
Extension delivery methods (= 1)	Any one of the household primary decision makers uses or participates in [the method] for agricultural information				
Farmer field day		0.10	0.30	0.10	0.30
Farm demonstration		0.16	0.36	0.15	0.36
Print materials		0.03	0.16	0.04	0.20
Radio		0.33	0.47	0.46	0.50
SMS/phone		0.04	0.19	0.05	0.23
Face-to-face visits		0.22	0.41	0.27	0.44
Community/group meeting		0.33	0.47	0.41	0.49
GVAC/VAC		0.14	0.34	0.15	0.35
Household-level characteristics					
Household head's education	Level of highest educational attainment by household head (0–23)	5.90	4.04	5.92	4.06
Household head's age		40.72	15.82	41.41	15.79
Household head's gender		0.75	0.43	0.76	0.43
Household size		5.07	2.39	5.26	2.25
Asset/wealth quintile (reference = poorest quintile)	Household asset index calculated using principal components analysis based on dwelling roof material, dwelling wall material, and the number of air conditioners, radios, cell phones, tape or CD players, televisions, refrigerators, washing machines, bicycles, motorcycles/scooters, cars, ox carts, power tillers and tractors				
Asset quintile 2		0.26	0.44	0.13	0.34
Asset quintile 3		0.19	0.40	0.21	0.41
Asset quintile 4		0.15	0.36	0.26	0.44
Asset quintile 5		0.22	0.42	0.17	0.38
Number of organizations		1.35	2.26	1.41	2.16
Received fertilizer subsidy (= 1)		0.30	0.46	0.25	0.43
Ganyu (hired labor)	Person-days per season	9.35	58.75	9.07	51.02
Crop acreage		1.76	1.79	1.98	17.72
Crop acreage squared		6.31	18.15	317.90	15959.79
Community-level variables					
Number of projects		3.01	1.61	2.19	1.48
Distance to nearest road quintile (reference = nearest)					
Distance quintile 2		0.17	0.38	0.22	0.41
Distance quintile 3		0.24	0.43	0.15	0.36
Distance quintile 4		0.20	0.40	0.21	0.41
Distance quintile 5 (farthest)		0.19	0.39	0.19	0.39

Variable	Definition	2016 (*N* = 2,938)		2018 (*N* = 2,771)	
		Mean	Std. Dev.	Mean	Std. Dev.
Extension agents in community	Number of extension agents working in the community	1.19	0.73	1.24	0.72
VAC is present in community (= 1)		0.53	0.50	0.62	0.49
Model village (= 1)	Community has started "model village" process (= 1)	0.20	0.40	0.34	0.48
Location- and climate-related controls					
Soil type (reference = best quality)	Soil type index calculated using principal components analysis based on whether it is affected by ponding, erosion, poor drainage, low cation exchange capacity, very low nitrogen, potassium, and phosphorous				
Soil type 2		0.24	0.42	0.24	0.42
Soil type 3 (poorest quality)		0.31	0.46	0.31	0.46
Slope		1.63	0.74	1.63	0.74
Max mean monthly temperature during survey year	Celsius	30.27	1.33	27.57	1.39
Max mean monthly temperature during year prior to survey	Celsius	29.63	1.45	27.86	1.42
Average mean monthly temperature during survey year	Celsius	23.37	1.34	22.12	1.49
Annual rainfall during survey year	Millimeters	969.77	95.91	1498.68	174.00
Annual rainfall during year prior to survey	Millimeters	1043.69	89.54	1384.75	244.27
Monthly rainfall (January prior to survey)	Millimeters	282.48	21.45	276.23	16.48
Monthly rainfall (February prior to survey)	Millimeters	201.05	13.02	213.95	15.01

Source of raw data: IFPRI household and community surveys (2016, 2018).
Note: NGO = nongovernmental organization; SMS = short message service; GVAC = group village agricultural development committee; VAC = village agricultural development committee.

Table A2 Quality of nearest neighbor matching on listening to radio programming in the last 12 months

Sample	Pseudo R^2	LR chi^2	*p* > chi^2	MeanBias	MedBias	B	R	%Var
Unmatched	0.078	337.5	0	12.7	7.7	68.3*	0.98	80
Matched	0.001	2.8	1	0.9	0.8	6.7	1.13	30

Note: Other matching techniques have similar results of significantly reducing the selection bias in the dataset. LR=Likelihood ratio; B=Rubin's B (the absolute standardized difference of the means of the linear index of the propensity score in the treated and (matched) non-treated group); R=Rubin's R (the ratio of treated to (matched) non-treated variances of the propensity score index) . Rubin (2001) and Morgan (2018) recommend that B be less than 25 and that R be between 0.5 and 2 for the samples to be considered sufficiently balanced. An asterisk is displayed next to B and R values that fall outside those limits. * If B > 25%, R outside [0.5;2].

REFERENCES

Achandi, E., G. Mujawamariya, A. R. Agboh-Noameshie, S. Gebremariam, and J. Rodenburg. 2018. “Women’s Access to Agricultural Technologies in Rice Production and Processing Hubs: A Comparative Analysis of Ethiopia, Madagascar, and Tanzania.” *Journal of Rural Studies* 60: 188–198.

Aker, J. 2011. “Dial ‘A’ for Agriculture: A Review of Information and Communication Technologies for Agricultural Extension in Developing Countries.” *Agricultural Economics* 42: 631–647.

Aker, J., I. Ghosh, and J. Burrell. 2016. “The Promise (and Pitfalls) of ICT for Agriculture Initiatives.” *Agricultural Economics* 47 (S1): 35–48.

Aker, J. C., and C. Ksoll. 2016. “Can Mobile Phones Improve Agricultural Outcomes? Evidence from a Randomized Experiment in Niger.” *Food Policy* 60: 44–51.

Beaman, L., A. BenYishay, J. Magruder, and A. M. Mobarak. 2015. “Can Network Theory–Based Targeting Increase Technology Adoption?” Draft paper. Accessed August 9, 2017. faculty.wcas.northwestern.edu/_lab823/MNW_june15.pdf.

Becker, S., and M. Caliendo. 2007. “Sensitivity Analysis for Average Treatment Effects.” *Stata Journal* 7 (1): 71–83.

BenYishay, A., and A. M. Mobarak. 2019. “Social Learning and Incentives for Experimentation and Communication.” *Review of Economic Studies* 86 (3): 976–1009.

Caliendo, M., and S. Kopeinig. 2008. “Some Practical Guidance for the Implementation of Propensity Score Matching.” *Journal of Economic Surveys* 22 (1): 31–72.

Chamberlain, G. 1984. “Panel Data.” In *Handbook of Econometrics.* Vol. 2, edited by Z. Grilliches and M. D. Intriligator, 1247–1318. Amsterdam: North-Holland.

Chapman, R., R. Blench, G. Kranjac-Berisavljevic, and A. B. T. Zakariah. 2003. *Rural Radio in Agricultural Extension: The Example of Vernacular Radio Programmes on Soil and Water Conservation in N. Ghana.* Network Paper 127. London: Agricultural Research and Extension Network, Overseas Development Institute.

Chapota, R., P. Fatch, and C. Mthinda. 2014. *The Role of Radio in Agricultural Extension and Advisory Services—Experiences and Lessons from Farm Radio Programming in Malawi*. MEAS (Modernizing Extension and Advisory Services) Case Study 8. U.S. Agency for International Development.

Chisama, B. F. 2016. “Farmers’ Use of Mobile Phone Technology for Agricultural Information Services in Lilongwe District, Malawi.” Purdue e-Pubs, Open Access Theses, 934. https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1915&context=open_access_theses.

Diagne, A., and M. Demont. 2007. “Taking a New Look at Empirical Models of Adoption: Average Treatment Effect Estimation of Adoption Rate and Its Determinants.” *Agricultural Economics* 37 (2–3): 201–210.

DiPrete, T., and M. Gangl. 2004. “Assessing Bias in the Estimation of Casual Effects: Rosenbaum Bounds on Matching Estimators and Instrumental Variables Estimation with Imperfect Instruments.” *Sociological Methodology* 34 (1): 271–310.

Fardon, R., and G. Furniss, eds. 2000. *African Broadcast Cultures: Radio in Transition*. Harare, Zimbabwe: Baobab Publishing; Oxford, UK: James Currey.

Feder, G., R. Just, and D. Zilberman. 1985. “Adoption of Agricultural Innovations in Developing Countries: A Survey.” *Economic Development and Cultural Change* 33 (2): 255–298.

Foster, A., and M. Rosenzweig. 2010. “Microeconomics of Technology Adoption.” *Annual Review of Economics* 2: 395–424.

FTF (Feed the Future) FEEDBACK. 2013. *Feed the Future Malawi: Zone of Influence Baseline Report.* Rockville, MD, US: Westat.

———. 2015. *Feed the Future Malawi 2015: Zone of Influence Interim Assessment Report.* Rockville, MD, US: Westat.

Fu, X., and S. Akter. 2016. “The Impact of Mobile Phone Technology on Agricultural Extension Services Delivery: Evidence from India.” *Journal of Development Studies* 52 (11): 1561–1576.

Hambly Odame, H., and A. Kassam. 2002. *Listening to Stakeholders: Agricultural Research and Rural Radio Linkages.* Briefing Paper 48. The Netherlands: ISNAR.

Hampson, K., M. Leclair, A. Gebru, L. Nakabugo, and C. Huggins. 2016. “ ‘There Is No Program without Farmers’: Interactive Radio for Forest Landscape Restoration in Mount Elgon Region, Uganda.” *Society and Natural Resources* 30 (5): 642–657.

Hirano, K., and G. W. Imbens. 2001. “Estimation of Causal Effects Using Propensity Score Weighting: An Application to Data on Right Heart Catheterization.” *Health Services and Outcomes Research Methodology* 2 (3–4): 259–278.

Holden, S. T., M. Fisher, P. K. Samson, and C. Thierfelder. 2018. “Can Lead Farmers Reveal the Adoption Potential of Conservation Agriculture? The Case of Malawi.” *Land Use Policy* 76: 113–123.

Hudson, H., M. Leclair, B. Pelletier, and B. Sullivan. 2017. “Using Radio and Interactive ICTs to Improve Food Security among Smallholder Farmers in Sub-Saharan Africa. *Telecommunications Policy* 41 (7–8): 670–684.

Kabunga, N., T. Dubois, and M. Qaim. 2012. “Heterogeneous Information Exposure and Technology Adoption: The Case of Tissue Culture Bananas in Kenya.” *Agricultural Economics* 43 (5): 473–486.

Katengeza, S. P., J. J. Okello, and N. Jambo. 2011. “Use of Mobile Phone Technology in Agricultural Marketing: The Case of Smallholder Farmers in Malawi.” *International Journal of ICT Research and Development in Africa* 2 (2): 14–25.

Kelemu, K., T. Haregewoin, and F. Daniel. 2016. “Impact of Radio on Technical Efficiency of Farmers: The Case of Wheat Producing Farmers in Ethiopia.” *Ethiop. J. Appl. Sci. Technol.* 7 (1): 1–15.

Kondylis, F., V. Mueller, and J. Zhu. 2017. “Seeing Is Believing? Evidence from an Extension Network Experiment.” *Journal of Development Economics* 125: 1–20.

Krishnan, P., and M. Patnam. 2014. “Neighbors and Extension Agents in Ethiopia: Who Matters More for Technology Adoption?” *American Journal of Agricultural Economics* 96 (1): 308–327.

Lambrecht, I., B. Vanlauwe, and M. Maertens. 2016. “Agricultural Extension in Eastern Democratic Republic of Congo: Does Gender Matter?” *European Review of Agricultural Economics* 43 (5): 841–874.

Larochelle, C., J. Alwang, E. Travis, V. Barrera, and J. M. Andrade. 2017. “Did You Really Get the Message? Using Text Reminders to Stimulate Adoption of Agricultural Technologies.” *Journal of Development Studies* 55 (4): 548–564.

Lwoga, E. T. 2010. “Bridging the Agricultural Knowledge and Information Divide: The Case of Selected Telecenters and Rural Radio in Tanzania.” *Electronic Journal of Information Systems in Developing Countries* 43 (1): 1–14.

Lwoga, E. T., and W. Chigona. 2020. “Telecenters and the Expansion of Human Capabilities among Rural Women.” *Global Knowledge, Memory, and Communication.* DOI: 10.1108/GKMC-11-2019-0136.

Malapit, H., C. Pinkstaff, K. Sproule, C. Kovarik, A. Quisumbing, and R. Meinzen-Dick. 2017. *The Abbreviated Women’s Empowerment in Agriculture Index (A-WEAI).* IFPRI Discussion Paper 1647. Washington, DC: International Food Policy Research Institute.

Morgan, C.J. 2018. “Reducing bias using propensity score matching.” *J. Nucl. Cardiol.* 25: 404–406.

Mudege, N., T. Nyekanyeka, E. Kapalasa, T. Chevo, and P. Demo. 2015. “Understanding Collective Action and Women’s Empowerment in Potato Farmer Groups in Ntcheu and Dedza in Malawi*.” Journal of Rural Studies* 42: 91–101.

Mundlak, Y. 1978. “On the Pooling of Time Series and Cross Section Data.” *Econometrica* 46: 69–85.

Musafiri, I. 2016. “The Role of Mobile Phones Use on Agricultural Output and Household Income in Rural Rwanda.” *International Journal of ICT Research in Africa and the Middle East* 5 (1): 58–68.

Nakasone, E., M. Torero, and B. Minten. 2014. “The Power of Information: The ICT Revolution in Agricultural Development.” *Annual Review of Resource Economics* 6: 533–550.

Norrish, P. 1998. “Radio and Video for Development.” In *The First Mile of Connectivity: Advancing Telecommunications for Rural Development through a Participatory Communication Approach,* edited by D. Richardson and L. Paisley. Rome: Food and Agriculture Organization of the United Nations.

Papke, L., and J. Wooldridge. 2008. “Panel Data Methods for Fractional Response Variables with an Application to Test Pass Rates.” *Journal of Econometrics* 145: 121–133.

Pirracchio, R., M. Resche-Rigon, and S. Chevret. 2012. ‘‘Evaluation of the Propensity Score Methods for Estimating Marginal Odds Ratios in Case of Small Sample Size.” *BMC Medical Research Methodology* 12:70; Open Access.

Ragasa, C. 2014. “Improving Gender-Responsiveness on Agricultural Extension.” In *Gender in Agriculture and Food Security: Closing the Knowledge Gap,* edited by A. Quisumbing, R. Meinzen-Dick, T. Raney, A. Croppenstedt, J. Behrman, and A. Peterman, 411–430. Springer.

Ragasa, C., N. L. Aberman, and C. Alvarez-Mingote. 2019. “Does Providing Agricultural and Nutrition Information to Both Men and Women Improve Household Food Security? Evidence from Malawi.” *Global Food Security* 20: 45–59.

Ragasa, C., and J. Mazunda. 2018. “The Impact of Agricultural Extension Services in the Context of a Heavily Subsidized Input System: The Case of Malawi.” World Development 105: 25–47.

Ragasa, C., and C. Niu. 2017. *The State of Agricultural Extension and Advisory Services Provision in Malawi: Insights from Household and Community Surveys.* IFPRI Technical Report (February). Washington, DC: International Food Policy Research Institute.

Roberts, E., B.A. Anderson, S. Skerratt, and J. Farrington. 2017. A review of the rural-digital policy agenda from a community resilience perspective. *Journal of Rural Studies* 54: 372-385.

Rosenbaum, R., and D. Rubin. 1983. “The Central Role of the Propensity Score in Observational Studies for Casual Effects.” *Biometrika* 70 (1): 41–55.

Rubin, D.B. 2001. "Using Propensity Scores to Help Design Observational Studies: Application to the Tobacco Litigation." *Health Services & Outcomes Research Methodology* 2: 169-188.

Salemink, K., D. Strijker, and G. Bosworth. 2017. “Rural Development in the Digital Age: A Systematic Literature Review on Unequal ICT Availability, Adoption, and Use in Rural Areas.” *Journal of Rural Studies* 54: 360–371.

Westermann, O., W. Forch, P. Thornton, J. Korner, L. Cramer, and B. Campbell. 2018. “Scaling Up Agricultural Interventions: Case Studies of Climate-Smart Agriculture.” *Agricultural Systems* 165: 283–293.

Wooldridge, J. 2002. *Econometric Analysis of Cross Section and Panel Data.* Cambridge, MA, US: MIT Press.

———. 2019. “Correlated Random Effects Models with Unbalanced Panels.” *Journal of Econometrics* 211 (1): 137–150.

Yadav, K., A. Kumar, R. Kumar, and R. S. Hudda. 2017. “Perception about Quality of Programme (PQP) and Impact Assessment of Community Radio Station on Farming Community.” *Research Journal of Agricultural Sciences* 8 (1): 168–171.

Young, J. 2019. “Rural Digital Geographies and New Landscapes of Social Resilience.” *Journal of Rural Studies* 70: 66–74.

Zossou, E., and M. Demont. 2019. “Impacting Consumer Valuation of Improved Local Parboiled Rice in Benin through Video and Rural Radio.” Paper presented at the Sixth African Conference of Agricultural Economists, Abuja, Nigeria, September 23–26.

ALL IFPRI DISCUSSION PAPERS

All discussion papers are available **here**

They can be downloaded free of charge

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
www.ifpri.org

IFPRI HEADQUARTERS

1201 Eye Street, NW
Washington, DC 20005 USA
Tel.: +1-202-862-5600
Fax: +1-202-862-5606
Email: ifpri@cgiar.org