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Can agricultural input subsidies reduce the gender gap in modern maize adoption? Evidence from Malawi

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ABSTRACT

Nationally representative data for Malawi were used to measure the gender gap in adoption of modern maize and to investigate how, if at all, Malawi's Farm Input Subsidy Program (FISP) has impacted the gap. Regression results show the probability of adopting modern maize was 12% lower for wives in male-headed households, and 11% lower for female household heads, than for male farmers. Receipt of subsidized input coupons had no discernible effect on modern maize adoption for male farmers. Receiving a subsidy for both seed and fertilizer increased the probability of modern maize cultivation by 222% for female household heads, suggesting the FISP has likely reduced the gender gap in adoption of modern maize in Malawi.

Introduction

In sub-Saharan Africa and other parts of the developing world, the use of modern seed varieties is essential for farmers to significantly increase their crop harvests and improve their living standards (Minten and Barrett, 2008). Nevertheless, certain groups of farmers, notably women, have relatively low rates of adoption of modern crop varieties and other agricultural technologies associated with increased crop yields (Peterman et al., 2010). Data for Malawi from the World Bank Living Standards Measurement Study (LSMS) show not only a recent decline in the use of modern maize seed, defined here as hybrid and open-pollinated varieties, but also a persistent gender gap in adoption of modern maize by female household heads and wives in male-headed households (MHHs), compared to male household heads (Fig. 1).[2]

The gender gap in adoption of modern crop varieties and other agricultural technologies is detrimental to the empowerment of women in developing countries, and imposes real costs on societies in terms of untapped potential in agricultural output, food security, and economic growth (Ragasa, 2012). In-depth studies indicate that, if women farmers had the same access as men to improved agricultural inputs, such as fertilizer and seed, maize yields would increase by as much as 16% in Malawi, 17% in Ghana, and 19% in western Kenya (World Bank, 2012). Furthermore, research in developing countries showed that income controlled by women has a greater positive effect than men's income on calorie intake, nutrition, health, and educational attainment of household members (Quisumbing et al., 1995; Thomas, 1997).

The present study used nationally representative data for Malawi from the 2010/11 Integrated Household Survey (IHS3) to (a) measure the gender gap in adoption of modern maize; (b) examine whether farmer gender influences adoption of modern maize when other factors are controlled for; and (c) investigate whether Malawi's Farm Input Subsidy Program (FISP) has impacted the gender gap. Female farmers in developing countries are less likely than male farmers to adopt modern seed varieties, but the relationship between gender and adoption generally becomes insignificant in regression analyses which control for access to resources that influence adoption of agricultural technologies (Chirwa, 2005; Doss and Morris, 2001; Smale, 2011). For example, Doss and Morris (2001) studied 420 Ghanaian farmers and found that the observed lower adoption rate among female farmers was not due to a lower propensity to adopt chemical fertilizer and modern maize seed, but reflected more limited access to complementary inputs, especially land, labor, and agricultural extension services.

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[2] Some plots in female-headed households were managed by husbands, but the number of these observations was very small ($n = 151$).

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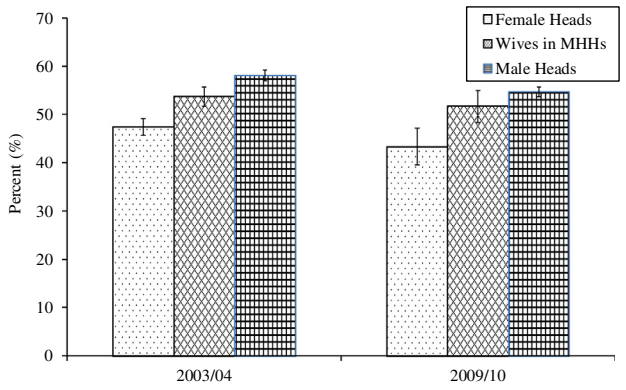

Fig. 1. Percentages of maize plots cultivated in modern maize and 95% confidence intervals for the percentages, by gender and relationship to head of the farm plot decision-maker, Malawi 2003/04 (n = 11,209) and 2009/10 (n = 12,475).

Limitations of previous studies suggest caution in drawing conclusions about gender differences in adoption of agricultural technologies. Previous research typically included only a few hundred observations, and might not have had the statistical power to detect gender differences. The exception is the study by Smale (2011), which was based on a nationally representative sample of over 1000 Kenyan households. Another problem is that previous research focused on the comparison between female and male household heads, and ignored the sizable number of married female farmers (Doss, 2001). A recent study found that gender of the plot manager significantly affected crop productivity, whereas gender of the household head did not (Peterman et al., 2011). Our study contributes to existing work by using a large, nationally representative dataset for Malawi for 2010/11, and by conducting the analysis at the plot level, which allowed us to compare plots managed by female household heads, wives in MHHs, and male household heads.

The current study complements research that evaluated the economic impacts of agricultural input subsidy programs (Ricker-Gilbert et al., 2011; Chibwana et al., 2012; Lunduka et al., 2013). Since 2005/06, the Malawian government has provided over a million farmers with annual subsidized coupons for maize seed and nitrogen fertilizer under FISP. Malawi has received wide recognition for the program, and has been hailed as the site of the first African green revolution (Denning et al., 2009). Neighboring countries have emulated Malawi by initiating agricultural input subsidy programs, but further evaluation of FISP's impacts on economic and social outcomes is needed.

FISP is thought to have differentially influenced adoption of modern maize among female and male farmers because the program was intended to target vulnerable households, including those headed by women. However, empirical evidence indicates that targeting was not successful in some years: in 2006/07 and 2008/09, FHHs were less likely than MHHs, and asset-poor households were less likely than wealthier households to receive coupons (Ricker-Gilbert et al., 2011; Chibwana et al., 2012). More optimistically, starting in 2009/10, agricultural extension officers worked with village leaders to identify beneficiaries and distribute coupons, increasing the probability that FHHs and other intended beneficiaries were selected for coupon receipt. Another reason FISP might have had a different influence on modern maize adoption of male vs. female farmers is that the program distributed coupons to household heads, with wives relying on their husbands for subsidized input coupon receipt.

This paper used data from the Malawi IHS3 to evaluate the impact of FISP on gender disparity in the adoption of new agricultural technologies. First, the analysis investigated factors associated with receipt of FISP coupons by households. Of primary interest was whether female- vs. male-headed households had different rates of coupon receipt. Second, the association between coupon receipt and the growing of modern maize was examined, using instrumental variables estimation to control for endogenous selection into the subsidy program. Third, we evaluated whether the receipt of FISP coupons had a differential effect on adoption of modern maize by female vs. male farmers, i.e., if the program influenced the gender gap. Finally, the empirical model simulated adoption rates for female household heads, wives in MHHs, and male household heads under several scenarios, to estimate the potential impact of FISP on Malawi's gender gap in modern maize adoption.

Data and definitions

The main source of data was the third Malawi Integrated Household Survey (IHS3) a World Bank LSMS conducted in 2010/11 that included survey results from the 2008/09 (15% of observations) and 2009/10 (85% of observations) agricultural years. The survey collected information at the village, household, individual, and farm plot levels, and merged these data with geographic data from other sources, using GPS coordinates of the villages and household dwellings. The present analysis included IHS3 data on agricultural production, household demographics, and household socioeconomic status; rainfall data from the U.S. National Oceanic and Atmospheric Association (NOAA); information on elevation from the International Food Policy Research Institute; and household distance to the nearest major road (primary and secondary networks), calculated from household GPS coordinates and Malawi's National Roads Authority data using geographic information systems (GIS).

We defined four farmer categories, based on gender and status in the household: female household heads, male household heads, wives in MHHs, and husbands in female-headed households (FHHs). Female household heads were defined as unmarried women (separated, divorced, widowed, or never married), women in monogamous marriages where the male spouse was absent more than six months of the year, and women in polygamous marriages who were recognized as the head of their household, because the husband was absent a considerable portion of the time. We defined male household heads as unmarried or married men who were the recognized household head. Wives were women in monogamous marriages or in polygamous marriages where the male spouse was the recognized head. Finally, husbands in FHHs were spouses in polygamous marriages where the woman was considered the household head, or spouses in monogamous marriages who were absent more than six months of the year.

Gender and agricultural production in Malawi

To assess the interrelationship between gender and agricultural production in rural Malawi, it is necessary to understand gender livelihood roles, and how women and men gain access to agricultural resources, especially land and labor.

Gender and access to, and control of, land

Smallholder agriculture in Malawi occurs largely on customary land, which accounts for approximately 80% of the total land area. Customary land is owned by the state, but control and administration is delegated to the chiefs of clearly-defined villages (Kishindo, 2004). Village chiefs have the right to allocate land within their jurisdiction, but the role of chiefs in land transfers in Malawi has diminished with increasing land scarcity. Today, women and men gain access to land primarily through inheritance and

Table 1a
Relationship to household head and gender of plot owners, by region of Malawi, 2008/09 and 2009/10.

Relationship to household head	Northern region		Central region		Southern region		Malawi	
	Male	Female	Male	Female	Male	Female	Male	Female
Head	1792 (78.7%)	391 (17.2%)	3622 (61.2%)	1083 (18.3%)	2503 (39.0%)	1719 (26.8%)	7917 (54.2%)	3193 (21.8%)
Spouse	63 (2.8%)	32 (1.4%)	29 (0.5%)	1182 (20.0%)	51 (0.8%)	2153 (33.5%)	143 (1.0%)	3367 (23.0%)

marriage. Different land transfer methods are mainly due to different descent practices, namely matrilineal and patrilineal. They are also based on residence status: in matrilocal contexts married men reside in their wife's village and in patrilocal contexts married women reside in their husband's village (Kishindo, 2004; Place and Otsuka, 2001). In patrilineal inheritance systems, which predominate in the north of Malawi, women cannot inherit their father's land. In matrilineal inheritance systems, which predominate in the central and southern regions, women inherit their mother's land. Thus, in general, women in patrilineal systems and men in matrilineal systems depend on their spouse to gain access to land. With increasing land scarcity, however, matrilineal–matrilocal systems are changing, and it is becoming more common for wives to be taken to their husbands' villages, and for parents to allocate land to their sons. This system is referred to as *chitengwa*. Neo-local residence – residing away from both the husband's and wife's villages – which was formerly unheard of in Malawi, is now practiced by some households. According to the IHS3, 51% of households were living in communities where the dominant inheritance-residence system was matrilineal–matrilocal, 26% were matrilineal–patrilocal or *chitengwa*, 6% were matrilineal-neo-local, 13% were patrilineal–patrilocal, and 4% were patrilineal-neo-local.

The IHS3 collected information on gender-based differences in the ownership and control of agricultural land. The average area cultivated by farmers during the 2008/09 and 2009/10 rain seasons was 2.25 acres, with MHHs cultivating larger farms than FHHs (2.41 vs. 1.75 acres, $p < 0.05$). Farm households owned or cultivated one to 10 plots, with 23%, 39%, 24%, 10%, and 5% of households operating one, two, three, four, and five or more farm plots, respectively. For plots owned (rather than rented or borrowed) by the sampled households, respondents were asked which household member was considered the plot owner. For cultivated plots, respondents were asked which household member was responsible for decisions regarding the crops to be planted, input use, and the timing of farming activities. The owner and the decision-maker were either the household head or the spouse for 99% of the farm plots. Other household members who owned or managed farm plots were parents, siblings, children, grandchildren, and nieces/nephews, but these individuals accounted for only 1% of plot ownership or management. For 77% of the owned plots, the owner and decision-maker was the same person.

The IHS3 data indicate that female farmers owned 45% of the farmed plots and male farmers owned 55% of the plots; but male farmers were the decision-makers for about 74% of the plots (Tables 1a and 1b). The discrepancy between the percentages of female spouses owning plots (23%) vs. managing plots (5%) might be explained by the matrilineal inheritance system widely practiced in the central and southern regions of Malawi. Under this system, women are considered the owners of land, but defer to their husbands on important household decisions, including those related to agriculture, as long as there is peace in the household. The data make clear that women in rural Malawi make decisions related to crop choice, input use, and timing of agricultural activities mainly when they are unmarried and the household head.

The IHS3 data show some differences in plot characteristics and crops grown based on gender and relationship to the household head (Table 2). Male household heads cultivated larger plots and managed more plots than female farmers. Male household heads provided higher estimates for the market value of their plots than did female household heads. No statistically significant differences were detected among the four groups in terms of soil attributes. Rain-fed agriculture was predominant for all categories.

In agreement with observed gender cropping patterns in Ghana (Doss, 2002), the IHS3 data suggest that few crops could be defined as 'men's crops', and none were primarily grown by women. Maize, Malawi's staple crop, is both a subsistence and a cash crop, and was the dominant crop grown on plots managed by all three groups of farmers, although the plots of male household heads were somewhat less dominated by maize than plots managed by female farmers (Table 2). Crop diversity was low for all groups, with male household heads and wives growing slightly more crops per plot than female household heads.

Gender and agricultural labor constraints

Labor is an essential input in agricultural production systems because most tasks require much time investment. This is particularly true in places like Malawi where there is limited use of animal traction and the hoe is the main farm tool. According to the World Development Report for 2012, only about 5% of Malawian farmers have access to mechanization. In Malawi, cultivation of modern maize varieties generally increases farm labor demand during the peak agricultural season because these varieties typically require fertilizer application. In contrast, local maize is commonly grown without fertilizer. As a result, adoption of modern maize can be impeded by limited availability of household or hired labor. Gender roles can influence a household's labor constraints and, therefore, the probability of adopting new agricultural technologies in societies where women and men perform different tasks or have differential access to household or hired labor.

Malawian farm households depend on household members to fulfill most of the labor requirements for maize production. Hired labor is limited, averaging only 2.2 days per farm plot per year, according to the IHS3. Female household heads hired fewer laborers to work their plots than did wives and male household heads. The Malawi IHS3 collected information on the numbers of elderly ($\geqslant$65 years), adult male and female (15–64 years), and child (6–14 years) household members engaged in three categories of agricultural tasks: land preparation and planting; weeding, fertilizing, and other non-harvest activities; and harvesting.[3] Table 3 provides labor supplied per acre for different agricultural activities for plots managed by female heads, wives in MHHs, and male heads. Results of the survey indicate a lack of gender division of labor for agricultural activities, consistent with previous field research in Malawi (Davison, 1993; Hirschmann and Vaughan, 1983). On a per-acre basis, women made up about half of the number of engaged household members in most tasks, although women's labor was less important on plots managed by male household heads.

Labor constraints are likely to be more pronounced in FHHs, which tend to be smaller and contain fewer adult males than MHHs. The IHS3 data show that plots managed by female

[3] The Malawi IHS3 also collected information on weeks, days per week, and hours per day worked by household members, but these data had very large numbers of missing values. Labor information for plots managed by husbands in FHHs was not examined, because these plots were so few in number.

Table 1b
Relationship to household head and gender of plot decision-makers, by region of Malawi, 2008/09 and 2009/10.

Relationship to household head	Northern region		Central region		Southern region		Malawi	
	Male	Female	Male	Female	Male	Female	Male	Female
Head	1754 (76.7%)	433 (18.9%)	4536 (76.6%)	1053 (17.8%)	4348 (67.3%)	1720 (26.6%)	10,638 (72.5%)	3206 (21.9%)
Spouse	29 (1.3%)	70 (3.1%)	57 (1%)	272 (4.6%)	65 (1%)	329 (5.1%)	141 (1.0%)	671 (4.6%)

household heads averaged 12.78 household members and 2.44 resident adult males per acre, compared to 13.49 and 7.67 for plots managed by male household heads (Table 3). Wives in MHHs had a higher number of household members working on their plots per acre, compared with plots managed by male and female household heads. Female household heads were disadvantaged in terms of access to adult male labor, but wives in MHHs were not disadvantaged in this respect. Compared to wives and male household heads, female household heads relied more on children and the elderly to carry out agricultural tasks.

Overall, the Malawi IHS3 data reveal gender gaps in access to, and control over, land and labor resources. Women's experiences varied: while wives and female household heads shared some common experiences, they differed significantly in terms of land ownership, plot management, and access to labor. For example, wives were the decision-makers for only 5% of farm plots, while the corresponding figure for female household heads was 22%. Wives' plots had more hired and household laborers working on agricultural activities than did female household heads' plots. These patterns are important to understanding the results of our empirical model.

Empirical approach

We used a two-step approach to empirically examine (a) the importance of farmer gender in adoption of modern maize varieties (Fig. 1); and (b) how, if at all, the Malawi FISP has impacted the gender differential in adoption of modern maize. In the first step, a multinomial logit (MNL) regression was used to predict the probability that a household received a subsidized input coupon under the FISP. In the second analysis step, a logit model was used to examine the factors, including coupon receipt, that determine adoption of modern maize. A two-step approach was needed because coupon receipt is potentially endogenous, due to correlation with unmeasured factors that influence modern maize adoption.

In recent years, the Malawi FISP entitled a beneficiary household to 2–5 kg of hybrid maize seed for free, and two 50 kg bags of fertilizer (23:21:0 + 4S basal and urea fertilizer) at about 8% of the prevailing market price (Chibwana et al., 2012). In practice, beneficiary households received different combinations of maize seed and fertilizer coupons. In the multinomial logit model (Eq. (1) below), the dependent variable C was categorical, with one category for no subsidized input coupon received, a second category indicating the household received a fertilizer coupon but no maize seed coupon, and a third category for households that received both a fertilizer and a maize seed coupon. We did not include a separate category for receipt of a maize seed coupon only, since 99.5% of households that received a maize seed coupon also received a fertilizer coupon.

$$C = \beta_0 + \beta_1 T + \lambda \boldsymbol{H} + \varphi \boldsymbol{L} + \omega \boldsymbol{Z} + v \quad (1)$$

The first explanatory variable, T, specifies the 2008/09 agricultural year, to account for differences in FISP between the two years covered by the IHS3. Vector $\boldsymbol{H}$ denotes characteristics of the household head and the household. Since the coupons were provided to household heads, characteristics of the household head and the household were critical in determining which households received coupons. The subsidy program was intended to benefit the most vulnerable farm households in each community, identified by village chiefs and Village Development Committees (VDCs). Variables indicating the household's level of vulnerability were expected to influence coupon receipt and were therefore included in Eq. (1): gender, age, and educational attainment of the household head; the size of the household's agricultural landholding; the household's wealth position; and the number of household members. The wealth level variable was created using principal component analysis (Filmer and Pritchett, 2001), based on components reflecting household ownership of physical assets (motorcycle, bicycle, radio, television, refrigerator, mobile phone, and livestock), access to utilities and infrastructure (electricity, main source of drinking water), and housing characteristics (type of wall, floor, and roofing material of the dwelling unit; type of toilet; number of rooms per person).

Household-level factors $\boldsymbol{H}$ also included a set of binary variables for whether or not the household received information about new seed in the last year from agricultural extension officers, other farmers, or the electronic media. A final variable in vector $\boldsymbol{H}$ was a binary variable for whether or not the household head was born in the village of current residence, a measure of social capital. We assumed that individuals born outside the village were less likely to be recognized by village leaders during coupon distribution than community members born in the village (Chibwana et al., 2012). To assess whether there were locational differences $\boldsymbol{L}$ in administration of the subsidy program, variables were included in Eq. (1) for the distance (km) to the nearest road and to indicate the household resided in the northern or central region.[4]

The two-stage instrumental variables model required inclusion of at least one variable in the coupon receipt equation that was not in the adoption equation. We used two variables $\boldsymbol{Z}$ thought to have influenced coupon receipt, but that did not directly affect the choice of what type of maize seed to cultivate. The first was a binary variable indicating whether a Member of Parliament (MP) resided in the community. Allocation of the subsidy coupons at the regional level was supposed to be based on the number of hectares under cultivation. However, there might have been some political influence on allocation, represented by the MP variable (Ricker-Gilbert and Jayne, 2011). The second identification variable was the number of months the household head was away from the village during the previous year. We hypothesized that if a household head was away frequently he or she was less likely to be present to receive a coupon, but that absenteeism would not have a direct influence on modern maize adoption, as long as the head could hire labor or rely on family members to cultivate the plot in his or her absence.

[4] It should be noted that the distance to road variable is measured with error for at least two reasons. First, distance to the nearest road measured using GIS gives a straight line distance rather than the actual distance that would be covered in traveling from the household dwelling unit to the nearest road. Second, to preserve the confidentiality of sample households and communities, latitudes and longitudes for the GIS variables were offset by specified amounts (see NSO, 2012, p. 31 for details).

Table 2
Characteristics of plots managed by female household heads, wives in MHHs, male household heads, and husbands in FHHs, Malawi 2008/09 and 2009/10.

Plot characteristics	Female household heads		Wives in MHHs		Male household heads		Husbands in FHHs	
	Mean or prop.	95% Conf. interval	Mean or prop.	95% Conf. interval	Mean or prop.	95% Conf. interval	Mean or prop.	95% Conf. interval
Area (acres)	0.879	0.858, 0.901	0.923	0.868, 0.978	1.013	0.996, 1.029	0.974	0.821, 1.127
Number of plots managed	2.088	2.056, 2.121	2.292	2.210, 2.374	2.460	2.440, 2.479	2.170	2.033, 2.306
Estimated value (US$)	282.97	267.52, 298.42	320.03	266.48, 373.58	377.27	361.51, 393.03	254.410	202.330, 306.490
Soil attributes								
Soil type is clay	0.175	0.163, 0.187	0.211	0.184, 0.238	0.188	0.181, 0.194	0.170	0.111, 0.228
Low soil erosion	0.877	0.867, 0.887	0.856	0.833, 0.880	0.881	0.876, 0.886	0.921	0.880, 0.963
Plot slope is flat	0.569	0.553, 0.584	0.540	0.507, 0.573	0.581	0.572, 0.589	0.600	0.524, 0.676
Rain-fed plot	0.996	0.994, 0.998	0.992	0.986, 0.998	0.995	0.994, 0.996	1.000	n/a
Main crop grown								
Maize	0.786	0.773, 0.799	0.760	0.732, 0.789	0.682	0.674, 0.690	0.736	0.668, 0.805
Tobacco	0.027	0.022, 0.032	0.035	0.023, 0.047	0.093	0.088, 0.098	0.056	0.020, 0.091
Legumes	0.098	0.089, 0.108	0.126	0.104, 0.148	0.123	0.117, 0.129	0.086	0.043, 0.129
Rice	0.037	0.031, 0.042	0.031	0.020, 0.043	0.035	0.032, 0.038	0.043	0.011, 0.074
Root crops	0.014	0.011, 0.018	0.029	0.018, 0.041	0.022	0.019, 0.024	0.018	-0.002, 0.039
Millet/sorghum	0.019	0.015, 0.023	0.010	0.004, 0.017	0.019	0.017, 0.022	0.037	0.008, 0.066
Cotton	0.014	0.010, 0.018	0.006	0.001, 0.011	0.017	0.015, 0.019	0.018	-0.002, 0.039
Number crops grown	2.003	1.998, 2.063	2.253	2.172, 2.335	2.402	2.383, 2.421	2.133	2.002, 2.264

Eq. (2) is a logit model that describes the relationship between modern maize adoption, A, and a set of explanatory variables hypothesized to influence adoption.

$$A = \alpha_0 + \alpha_1 T + \alpha_2 R + \theta \boldsymbol{I} + \delta \boldsymbol{P} + \gamma \boldsymbol{H} + \mu \boldsymbol{L} + \pi \boldsymbol{C}^{*} + \varepsilon \quad (2)$$

The dependent variable, A, is a binary variable indicating whether modern maize was cultivated on the farm plot. The farm plot was the relevant analysis unit since many of the sampled farm households operated multiple plots and cultivated these plots in different maize varieties. The selection of explanatory variables for Eq. (2) was based on review of literature on adoption of agricultural technology in low-income settings (Doss, 2006; Feder et al., 1985; Foster and Rosenzweig, 2010).

The first explanatory variable, T, accounts for differences in adoption probability between 2008/09 and 2009/10. R is a binary variable indicating whether the plot decision-maker was the respondent during the interviews. R controls for measurement error in cases where a household member other than the plot manager responded to questions (Fisher et al., 2010). Vector $\boldsymbol{I}$ denotes characteristics of the plot decision-maker: binary variables for whether the plot manager was a female household head or a wife (male household head is the reference category); variables for the age and education of the plot decision-maker; and a binary variable for whether the plot manager was from outside the village of current residence. $\boldsymbol{P}$ represents plot attributes: area (measured by GPS device); a binary variable indicating whether the plot had market-based tenure (purchased, leasehold, and rented land) as opposed to customary tenure; and the market value of the plot, estimated by the respondent.

The household-level factors $\boldsymbol{H}$ hypothesized to influence adoption of modern maize include variables for labor supply (number of adults and older children in the household); access to cash or credit to purchase seed (wealth level, non-labor income, and access to credit); access to information about new seeds from government agricultural extension officers, other farmers, or electronic media; and subjective drought risk, as measured by an affirmative response that the household was negatively impacted by drought in the last year. The credit variable indicates that household members were denied credit or did not seek out credit in the past year, because they believed they would be refused, they did not know any lender, they had inadequate collateral, or they considered borrowing to be too costly.

The locational factors, $\boldsymbol{L}$, include a variable for distance (km) to the nearest major road (primary and secondary network) to measure agricultural market access; total precipitation (mm) in the last year and elevation (m) of the village, which reflect maize growing conditions; and region of residence variables, which capture other agro-ecological, social, and economic conditions that influence adoption of agricultural technologies.

Vector $\boldsymbol{C}^{*}$ includes two continuous variables measuring the probability a household received a fertilizer coupon only and the probability a household received both a maize seed and a fertilizer coupon. These variables were predicted probabilities from the multinomial logit regression of coupon receipt (Eq. (1)). It was important to categorize coupon receipt in this way to account for the different incentives for modern maize adoption based on whether or not modern maize seed was part of the received subsidy. In households where maize seed coupons were received, adoption of modern seed was directly tied to the subsidy program. If farmers received subsidized fertilizer only (i.e. their subsidy package did not include free maize seed) their use of modern seed was promoted but not guaranteed. If these households grew modern maize they made a decision to use their resources to purchase modern seed, i.e. the household decided to adopt modern maize.

Table 3
Numbers of household members engaged in agricultural activities per acre on plots managed by female heads, wives in MHHs, and male heads, Malawi 2008/09 and 2009/10.

Plot characteristics	Female heads		Wives in MHHs		Male heads	
	Mean	95% C.I.	Mean	95% C.I.	Mean	95% C.I.
Land preparation and planting						
Elderly	0.52	0.44, 0.59	0.14	0.10, 0.19	0.21	0.19, 0.24
Men	0.87	0.77, 0.97	2.00	1.56, 2.45	2.21	2.12, 2.29
Women	2.42	2.26, 2.59	2.87	2.38, 3.36	2.01	1.94, 2.08
Children	0.60	0.54, 0.66	0.62	0.41, 0.84	0.29	0.26, 0.31
Total	4.41	4.17, 4.65	5.65	4.83, 6.46	4.72	4.57, 4.86
Weeding, fertilizer, and other non-harvest activities						
Elderly	0.52	0.44, 0.60	0.13	0.09, 0.18	0.21	0.18, 0.24
Men	0.83	0.73, 0.93	1.80	1.42, 2.17	2.13	2.06, 2.21
Women	2.36	2.20, 2.52	2.67	2.21, 3.14	1.95	1.88, 2.01
Children	0.58	0.52, 0.64	0.69	0.46, 0.93	0.28	0.26, 0.30
Total	4.30	4.06, 4.53	5.29	4.56, 6.02	4.57	4.43, 4.70
Harvest activities						
Elderly	0.51	0.42, 0.60	0.14	0.09, 0.18	0.19	0.17, 0.21
Men	0.74	0.65, 0.84	2.09	1.53, 2.65	1.85	1.78, 1.91
Women	2.21	2.04, 2.38	2.45	1.92, 2.98	1.86	1.79, 1.93
Children	0.62	0.55, 0.68	1.03	0.25, 1.81	0.31	0.28, 0.34
Total	4.08	3.83, 4.33	5.70	3.98, 7.42	4.21	4.07, 4.34
Agricultural activities						
Elderly	1.55	1.32, 1.78	0.41	0.29, 0.53	0.61	0.54, 0.69
Men	2.44	2.16, 2.72	5.89	4.66, 7.12	6.19	5.98, 6.40
Women	6.99	6.51, 7.48	7.99	6.60, 9.39	5.82	5.62, 6.02
Children	1.80	1.63, 1.96	2.34	1.42, 3.27	0.87	0.81, 0.93
Total	12.78	12.08, 13.49	16.64	13.60, 19.68	13.49	13.09, 13.89

Empirical results and discussion

FISP coupon receipt

Table 4 presents marginal effects and *z*-statistics for the multinomial logit model of FISP coupon receipt. Results indicate there was no significant difference in the probability of FISP coupon receipt between households headed by females vs. males. Contrary to FISP targeting guidelines, there was a positive correlation between farm size and coupon receipt, and households at the bottom 40% of the wealth distribution were less likely than better-off households to receive coupons for both maize seed and fertilizer. Evaluations of FISP for 2006/07 and 2008/09 similarly found that better-off households were targeted under the program (Ricker-Gilbert et al., 2011; Chibwana et al., 2012).

Model results show the likelihood of coupon receipt was positively related to the age of the household head (Table 4), perhaps because older farmers had lived long enough to develop strong social connections to their village leaders. Political or social motivations might have influenced identification of beneficiaries by village leaders. Number of household members was positively correlated with a household receiving both a maize seed and a fertilizer coupon. As expected, access to information from government extension officers or the electronic media had a positive influence on the probability a household received both coupon types, because awareness of important program information from extension officers and the media increased the likelihood that a farmer would be present during coupon distribution. But information from electronic media was negatively associated with receipt of a fertilizer coupon only, a finding that is difficult to explain. Findings suggest that, compared with households headed by an individual from outside the village, households with a head born in the current village of residence were more likely to receive the full FISP package consisting of both fertilizer and maize seed coupons.

Multinomial logit results indicate some locational differences in administration of the subsidy program (Table 4). Geographic remoteness did not appear to hinder program participation, since distance to the nearest road had a positive association with receipt of a fertilizer coupon. Compared to households in the south, northern region households were less likely to receive subsidized fertilizer only and more likely to get coupons for both maize seed and fertilizer. Compared to households in the south, central region households were more likely to receive subsidized fertilizer only and less likely to get coupons for both inputs.

Interestingly, farmers residing in communities where a Member of Parliament was resident or recently visited were more likely to receive a FISP package consisting of fertilizer only, but were less likely to receive both fertilizer and maize seed coupons (Table 4). The MP variable was statistically significant, providing some support for instrument validity. Number of months the household head was away in the last year was not significantly correlated with coupon receipt, perhaps because other household members collected the coupons in the head's absence. Pairwise correlations between the modern maize adoption variable A (Eq. (2)) and the identifying instruments provided additional empirical support for instrument validity. The correlations were statistically insignificant ($p \leqslant 0.05$) for both variables. Furthermore, when the two identifying instruments were included in the modern maize adoption regression, the variables were statistically insignificant.[5]

Factors associated with adoption of modern maize varieties

Logit results for modern maize adoption provide insight into the influence of control variables and key variables, i.e., variables representing gender of the farm plot decision-maker and FISP coupon use (Table 5). Modern maize adoption was higher in 2009/10 than in 2008/09. Older farmers were less likely to grow modern maize than younger farmers. Farm plot managers with a primary school education or higher were more likely to grow modern maize than less-educated farmers, supporting previous evidence that educated individuals are better able to quickly and effectively process information about new technologies (Foster and Rosenzweig, 2010).

[5] While the empirical tests indicate the MP variable is weakly related to seed adoption, it deserves mention that Members of Parliament use their political meetings with community members to pass on development messages, particularly those related to food security issues.

Table 4
Multinomial logit regression for FISP coupon receipt ($n = 9571$).

Explanatory variable	Fertilizer coupon only		Maize seed and fertilizer coupon	
	Marginal effect[a]	z-Value[b]	Marginal effect[a]	z-Value[b]
Agricultural year 2008/09	0.028	1.98	−0.0001	−0.01
Household-level variables				
Female household head	0.003	0.24	0.014	1.26
Age of the household head (years)	0.002	6.74	0.001	4.17
Household head had primary education or higher	−0.026	−2.13	−0.019	−1.76
Agricultural landholding (acres)	0.016	4.67	0.013	4.76
Wealth poor (bottom 40% of wealth-index distribution)	−0.019	−1.88	−0.028	−3.09
Number of household members	0.002	0.77	0.009	4.73
Information on new seed from govt. extension, last year	0.006	0.42	0.127	8.81
Information on new seed from other farmers, last year	−0.005	−0.18	−0.033	−1.47
Information on new seed from electronic media, last year	−0.052	−3.09	0.065	3.76
Household head from outside the district	−0.077	−7.59	−0.030	−3.23
Locational factors				
Household distance to nearest major road (km)	0.003	5.93	0.0003	0.79
Residence northern region	−0.073	−5.19	0.085	6.32
Residence central region	0.071	6.21	−0.107	−11.38
Instrumental variables				
MP resident of or recently visited community (0/1)	0.027	2.35	−0.025	−2.56
Number of months household head was away last year	0.007	1.45	−0.005	−1.13

[a] Marginal effects indicate percentage point rather than percentage change. To arrive at percentage figures, the marginal effects must be divided by the predicted probability of receiving a fertilizer coupon only (0.318) or both a maize seed and fertilizer coupon (0.218).
[b] z-Values are based on Huber–White robust standard errors.

Findings in Table 5 indicate the decision to grow modern maize was consistent with induced innovation, whereby land scarcity encourages farmers to intensify agricultural production (Boserup, 1981). There was a greater tendency to grow modern maize on plots that farmers subjectively rated as being of higher quality. Thus, farmers with what they considered to be good agricultural land appear to have had greater incentive to invest in the knowledge required to adopt new seed varieties (Place and Otsuka, 2001).

Greater availability of adult male and child labor was associated with a higher probability of growing modern maize (Table 5). Plots were more likely to be planted in modern maize if they were managed by an individual from a household that was not wealth poor and that had non-labor income. Transmission of information from farmer to farmer positively influenced adoption of modern maize. Farm plot managers were less likely to grow modern maize if their household had been negatively impacted by drought during the past year. Local maize varieties might have performed better under drought conditions than the available modern varieties, which were not bred for drought tolerance, or farmers might have perceived this to be the case. Alternatively, the drought variable result might reflect farmer risk perception: risk-averse farmers are less willing to take on the risks, both subjective and objective, that innovations entail (Feder et al., 1985).

Poor market access increases a farmer's production costs and reduces profits, and therefore should be associated with reduced adoption of new agricultural technologies. Consistent with this expectation, distance to the nearest major road was negatively associated with adoption of modern maize. Agro-ecological conditions were influential factors: plots in localities with favorable growing conditions – relatively high rainfall and low elevation – were more likely to be planted in modern maize. Finally, maize plots in the northern region were less likely, to be planted in modern maize than plots in the south.

Surprisingly, at standard test levels ($p < 0.05$), neither of the predicted coupon receipt variables was significantly associated with modern maize adoption, although both variables have the expected positive sign. In particular, it comes as a surprise that receipt of a package consisting of both fertilizer and maize seed did not significantly influence the growing of modern maize seed.

Regression results show that farmer gender had a significant influence on adoption of modern maize (Table 5). Controlling for other important factors, female household heads had an 11% lower probability, and wives in MHHs had a 12% lower probability of growing modern maize than male household heads (see note a. in Table 5 for an explanation of how these percentages were calculated from the marginal effects). In contrast, previous studies found that gender differences in adoption disappeared, once controls for access to land, labor, capital, extension services, and markets were included (Chirwa, 2005; Doss and Morris, 2001; Smale, 2011). Those studies were based on small samples, typically a few hundred households, so their empirical models might not have had sufficient statistical power to detect gender-based differences in adoption probability. Alternatively, the importance of gender to adoption of agricultural technology could depend on context and time. There is enormous complexity and heterogeneity among households in sub-Saharan Africa, and gender roles and responsibilities change with new economic circumstances (Doss, 2001).

A key research implication of the results for the gender variables in Table 5 is that reduced access to complementary inputs is only a partial explanation for why gender of the farmer influences adoption of modern maize in Malawi. Further analysis to reveal other explanations is needed. Another possible explanation is that men and women have different preferences for variety characteristics, but because crop breeders typically do not consult female farmers, modern varieties generally do not match the specific

Table 5
Logit regression explaining adoption of modern maize seed on maize plots (n = 11,051).

Variable	Marginal effect[a]	z-Value[b]
Agricultural year 2008/09	−0.054	−3.27
Respondent was plot manager	0.017	1.42
Characteristics of plot decision-maker		
Age (years)	−0.004	−6.18
Primary education or higher	0.060	4.18
From outside the district	−0.033	−1.83
Plot characteristics		
Area (acres)	−0.052	−6.30
Market-based tenure	0.060	1.90
Estimated market value (US$1,000)	0.024	3.00
Household-level variables		
Number of female adults (15–64 years)	0.007	0.87
Number of male adults (15–64 years)	0.022	2.97
Number of children (6–14 years)	0.013	2.77
Wealth poor (bottom 40% of wealth-index distribution)	−0.070	−5.28
Non-labor income last year	0.027	2.06
Limited access to credit	−0.021	−1.91
Information on new seed from govt. extension, last year	0.048	1.62
Information on new seed from other farmers, last year	0.156	5.38
Information on new seed from electronic media, last year	0.024	1.01
Negatively affected by drought in the last year	−0.027	−2.27
Locational factors		
Household distance to nearest major road (km)	−0.003	−4.27
Total precipitation (mm), last year	0.001	8.23
Elevation (m)	−0.0001	−5.59
Residence northern region	−0.110	−3.31
Residence central region	0.035	1.25
Predicted FISP coupon receipt		
Fertilizer coupon only	0.206	1.11
Maize seed and fertilizer coupon	0.222	1.11
Gender of plot decision-maker		
Female head	−0.057	−4.03
Wife in MHH	−0.059	−2.34

[a] To arrive at percentage figures, the marginal effects must be divided by the predicted probability of modern maize adoption (0.494).
[b] Because the unit of analysis was the maize plot, standard errors were adjusted for within-cluster (household) correlation, using the household identifier variable.

criteria of women farmers (Lunduka et al., 2012; Quisumbing and Pandolfelli, 2010). In addition, lower adoption levels among female farmers could reflect intrinsically higher risk aversion among women, and less willingness to take on the inherent risks that new agricultural technologies entail (Feder et al., 1985). Although these hypotheses have not been directly tested, there is some evidence to support them. Research in Mexico showed that male farmers generally assigned greater importance to production attributes of maize (e.g., yield), while female farmers put greater emphasis on consumption characteristics (e.g., good for cooking) and vulnerability traits (e.g., tolerance to excess rainfall) (Bellon et al., 2006). These differences are predictable, considering that males are more often responsible for crop commercialization, and that females are more often responsible for maize processing and preparation. Furthermore, a review of economic laboratory and field experiments on risk preferences consistently found higher risk aversion among females than males (Croson and Gneezy, 2009).

Gender-based differences in the factors associated with adoption of modern maize

Logit regression analysis was used to assess whether there were gender-based differences in factors associated with adoption of modern maize and, in particular, if receipt of FISP coupons differentially affected adoption rates by female household heads, wives in MHHs, and male household heads. It is striking how poorly the regression model explained adoption of modern maize by wives: only four variables had statistically significant effects (Table 6). Availability of female household labor and access to information about new varieties from government extension officers were strong predictors of modern maize adoption on plots managed by wives. Wives' plots that had market-based tenure were less likely to be planted in modern maize than plots that had no formal tenure agreement, which is an unexpected finding and difficult to explain. The lack of statistical significance for parameters of the wives' sub-sample probably reflects the relatively small sample size (n = 483). Furthermore, a model that incorporates potential conflict and bargaining between husbands and wives is likely more consistent with the decision-making process of wives who manage farm plots (Fisher et al., 2000; Lilja et al., 1996).

The empirical adoption model performed better for plots managed by female and male household heads, and detected some interesting similarities and differences between these two groups. Marginal effects for plots of female and male household heads were in the same direction for the following variables: agricultural year, age, education, area of the farm plot, information from farmers, previous year's rainfall, and elevation above sea level. Explanatory variables that had a significant influence only on male household heads included being from outside the village, estimated market value of the managed plot, numbers of adult male and child members in the household, household wealth level, information from government extension and the electronic media, distance to the nearest major road, and residence in the north.

Non-labor income was the only control variable that had a significant influence on female, but not male, household head adoption of modern maize. Non-labor income was especially influential among *de facto* female household heads, whose husbands migrated for work and sent remittances to the family. Surprisingly, the availability of household labor did not influence modern maize adoption by female household heads. The lack of a significant effect of information from government extension and the electronic media on female household heads' adoption might indicate limited access to information from these sources, or that these sources provided information in a manner that was not useful to female farmers. Overall, results of the adoption model suggest that male and female household heads represented somewhat different demand segments in the market for modern maize seed, consistent with the results of Smale and Mason (2012).

The influence of FISP coupon receipt on adoption of modern maize by male and female farmers was of particular interest. Results indicate that coupon receipt had no discernible influence on the adoption of modern maize by wives in MHHs or by male household heads. Adoption by female household heads was, however, significantly influenced by receipt of a FISP package consisting of both maize seed and fertilizer coupons. The marginal effect indicates that receipt of both input coupons was associated with a 222% increase in the probability of modern maize adoption by female household heads. The very large magnitude of this effect relative to the marginal effects of other explanatory variables raises the question of whether we observe real adoption or if cultivation of modern maize varieties by female household heads merely reflects access to free seed under the FISP.

Initial consideration of the adoption model results seem to indicate that FISP reduced the modern maize adoption gap between male and female household heads in Malawi. First, male and female household heads did not have differential probabilities of FISP coupon receipt, during the 2008/09 and 2009/10 agricultural years (Table 4). Second, receipt of a FISP package consisting of both maize seed and fertilizer greatly increased modern maize adoption

Table 6
Logit regressions explaining adoption of modern maize seed on maize plots, by gender and relationship to the household head.

Variable	Female heads (n = 2,776)		Wives in MHHs (n = 483)		Male heads (n = 7,792)	
	Marg. eff.[a]	z-Value[b]	Marg. eff.[a]	z-Value[b]	Marg. eff.[a]	z-Value[b]
Agricultural year 2008/09	−0.071	−2.24	0.014	0.17	−0.056	−2.78
Respondent was plot manager	0.020	0.45	0.102	1.78	0.012	0.88
Characteristics of plot decision-maker						
Age (years)	−0.005	−4.00	−0.004	−1.26	−0.004	−4.99
Primary education or higher	0.141	3.57	0.110	1.38	0.050	3.14
From outside the district	−0.029	−0.70	0.042	1.06	−0.049	−5.22
Plot characteristics						
Area (acres)	−0.095	−4.38	0.076	1.27	−0.051	−2.22
Market-based tenure	0.096	1.27	−0.240	−2.08	0.067	1.86
Estimated market value (US$1,000)	0.018	0.95	−0.008	−0.19	0.026	2.52
Household-level variables						
Number of female adults (15–64 years)	−0.003	−0.20	0.128	3.40	0.002	0.18
Number of male adults (15–64 years)	0.011	0.74	0.043	1.46	0.025	2.79
Number of children (6–14 years)	0.006	0.58	0.002	0.10	0.014	2.40
Wealth poor (bottom 40% of wealth-index distribution)	−0.007	−0.27	−0.009	−0.15	−0.088	−5.65
Non-labor income last year	0.061	2.71	0.007	0.11	0.011	0.69
Limited access to credit	−0.040	−1.83	−0.019	−0.35	−0.014	−1.09
Information on new seed from govt. extension, last year	−0.077	−1.19	0.229	1.97	0.071	2.15
Information on new seed from other farmers, last year	0.160	2.98	0.230	1.76	0.156	4.40
Information on new seed from electronic media, last year	−0.066	−1.29	−0.119	−1.10	0.057	2.09
Negatively affected by drought in the last year	−0.018	−0.74	−0.069	−1.26	−0.026	−1.88
Locational factors						
Household distance to major road (km)	−0.003	−1.83	−0.003	−0.83	−0.004	−4.30
Total precipitation (mm), last year	0.001	4.27	0.0002	0.56	0.001	6.97
Elevation (m)	−0.0001	−2.11	−0.0002	−1.98	−0.0001	−4.89
Residence northern region	−0.116	−1.85	0.103	0.70	−0.096	−2.29
Residence central region	0.077	1.32	0.005	0.05	0.013	0.39
Predicted FISP coupon receipt						
Fertilizer coupon only	0.507	1.19	−0.415	−0.82	0.347	1.48
Maize seed and fertilizer coupon	0.924	2.03	−0.326	−0.38	0.070	0.30

[a] To arrive at percentage figures, the marginal effects must be divided by the predicted probabilities of modern maize adoption, which are 0.417 (female heads), 0.470 (wives in MHHs), and 0.522 (male heads).
[b] Because the unit of analysis was the maize plot, standard errors were adjusted for within-cluster (household) correlation, using the household identifier variable.

probability for female household heads, but coupon receipt had no statistically significant influence on the adoption probability of male farmers. It is unlikely that the difference in modern maize adoption between wives and male household heads was reduced as a result of FISP. We did not examine intra-household distribution of coupons received by the household head, but Chirwa et al. (2011) showed that in households that received FISP subsidized fertilizer there was no bias in the likelihood of application of fertilizer to female vs. male managed plots. Coupon receipt at the household level did not significantly influence modern maize adoption for either wives in MHHs or male household heads.

The effect of FISP on the gender gap in adoption of modern maize

The logit adoption model was used to run three simulations that investigated how recent rounds of FISP might have affected the gender gap in modern maize adoption rates in Malawi, and how targeting of subsidized input coupons to female-headed households could potentially influence the gender gap (Table 7). The simulations predicted adoption rates for plots managed by female household heads and male household heads, using the FISP coupon receipt variables as those of primary interest. We did not run simulations for plots managed by wives in MHHs due to the poor fit of the logit adoption model for that sub-sample. For the simulations, all the control variables were held at their mean values, assuming that changes in coupon receipt would not affect other model parameters. Separate simulations were performed for the two groups of plot decision-makers.

Scenario 1 predicted modern maize adoption rates for female and male farmers under the observed situation, where 27.85% (95% CI = 26.23, 29.47) of FHHs received a fertilizer coupon only and 19.56% (95% CI = 18.12, 20.99) received both a maize seed and a fertilizer coupon. Corresponding figures for MHHs were 25.13% (95% CI = 24.25, 26.02) and 18.21% (95% CI = 17.43, 19.00). Scenario 2 assumed that FISP did not exist, and that farmers purchased maize seed and chemical fertilizer at the prevailing market prices. Finally, Scenario 3 assumed that FHHs were the primary targets of the FISP. We assigned the available coupons for the 2008/09 and 2009/10 years to FHHs first (77% received both maize seed and fertilizer coupons and 23% received a fertilizer coupon only). The remaining coupons, after all FHHs were reached, went to MHHs (27% received a fertilizer coupon only).

Model simulation results are presented in Table 7. The simulated results for Scenario 1 are in good agreement with observed adoption rates, which were 42.15% and 52.14% for female household heads and male household heads, respectively. Simulation results for Scenarios 1 and 2 show that FISP was associated with a 177% and a 31% increase in modern maize adoption for female and male household heads, respectively. However, the differences between modern adoption with and without the FISP were statistically significant only for the female household head sample. This result parallels the earlier results in Table 6 showing that FISP had a very large positive association with modern maize adoption among female household heads but did not influence adoption among male farmers. In tandem these results suggest the FISP has narrowed, though not eliminated, the differential rate of modern maize adoption between female and male household heads. These findings also highlight how important receipt of subsidized seed is for FHHs to adopt modern maize. Comparing simulation results for Scenarios 1 and 3 suggests that targeting of FISP coupons

Table 7
Simulation results for adoption probability based on the modern maize adoption model.

	Predicted probability of adopting MV maize [95% confidence interval]	
	Female heads	Male heads
Scenario 1: Observed coupon receipt	41.68 [39.79, 43.52]	52.28 [51.11, 53.43]
Scenario 2: Hypothetical situation where nobody would receive a FISP coupon	15.01 [3.00, 39.15]	40.06 [24.84,57.11]
Scenario 3: Hypothetical situation where coupons would be targeted to FHHs	78.25 [45.01, 95.83]	48.84 [38.63, 59.13]

to FHHs could potentially eliminate the gender gap in modern maize adoption between FHHs and MHHs, but the large amount of variability in these estimates means we are unable to state this conclusion with any reasonable degree of statistical confidence.

Conclusions

Results of the present study provide insight into two important scholarly and policy questions. First, how important is gender in explaining patterns in adoption of new agricultural technologies? Second, how effective are subsidy programs in encouraging adoption of new agricultural technologies, particularly by women farmers? Empirical evidence concerning the effectiveness of input subsidy programs in general, and more specifically as an approach to improve the economic well-being of women farmers, is crucial to policy makers. Malawi provides a useful case, because the country has had a long-term commitment to agricultural input subsidies, and because it is a learning case for other countries in the region who are considering agricultural input subsidy programs.

Our study extends existing work in several ways. Unlike previous studies based on small sample sizes, we used the large, nationally representative dataset from the 2010/2011 Malawi IHS3. These data made it possible to evaluate similarities and differences between female household heads, male household heads, and wives in MHHs at the plot level. We used multinomial logit and logit regression models to examine the effectiveness of FISP targeting and the salience of gender in explaining modern variety adoption gaps, and we employed instrumental variables estimation to control for endogenous coupon receipt. Finally, we used different simulation scenarios, based on the empirical adoption model, to directly examine the potential impact of FISP on modern maize adoption by female and male farmers. The simulations allowed us to compare what would happen to the gender gap between female and male household heads if no one received coupons and if the coupons were targeted to FHHs.

Contrary to results of previous studies (Chirwa, 2005; Doss and Morris, 2001; Smale, 2011), we found gender was an important determinant of modern maize adoption, even after controlling for individual, household, and community-level characteristics. FISP coupon use was associated with an overall increase of 222% in the probability of modern maize adoption for female household heads, but did not impact adoption probability for wives in MHHs or male household heads. Simulations for scenarios with and without FISP suggest the FISP increased modern maize adoption by about 177% and 31% for female and male household heads, respectively. However, the difference with and without FISP was only statistically significant for the case of female household heads, which suggests the FISP likely narrowed this gender gap in modern maize adoption. The results indicate that targeting FISP towards FHHs, could substantially reduce, or even eliminate, the gender gap in adoption of modern maize, but we are unable to state this conclusion with any reasonable degree of statistical confidence.

Study results have important implications for future research. First, more information is needed to understand why female farmers are less likely than male farmers to adopt modern maize varieties, and why many female household heads only grow modern maize if they receive free seed, even when controlling for wealth level, non-labor income, and access to credit. Gender-disaggregated data on farmers' preferences for specific variety traits and attitudes toward risk would be particularly useful. Second, additional information is needed to better understand factors that specifically influence adoption decisions by wives in MHHs, e.g., how intra-household dynamics influence modern maize adoption. Qualitative research methods, such as in-depth interviews, could provide insight into how husbands and wives negotiate agricultural decisions, and could elucidate how gender norms shape agricultural technology preferences and risk profiles.

Finally, results of the present study have important policy implications, in particular, that input subsidy programs can play a role in making modern farm technologies, such as modern seed, accessible to female farmers. Beyond ensuring that female farmers have access to improved technologies, separate policies that are specifically aimed at female household heads vs. wives in MHHs might be needed to completely eliminate the gender gap in adoption of modern maize in Malawi.

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