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ORIGINAL PAPER

Exploring agriculture-child nutrition pathways: Evidence from Malawi's Farm Input Subsidy Program

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Abstract
Child undernutrition is highly prevalent around the world, particularly in low-income countries where economies are largely driven by the agricultural sector. Agricultural policies have the potential to impact total food production as well as food quality and diversity, thereby shaping nutritional status. In this study, we first corroborate evidence that Malawi's Farm Input Subsidy Program (FISP), which provides subsidized vouchers for farm inputs to targeted rural households, boosts child nutritional status. Our analysis includes recent years during which the program's nutrition impacts have not been previously examined. We then investigate three broad categories of agriculture-child nutrition linkages in the context of this program: (1) farm production and diversity, (2) crop sales, non-farm enterprises, and food consumption from different sources (purchases and own production), and (3) women's empowerment and the health environment. In order to identify plausibly causal estimates, we employ a fixed effects-instrumental variable (FE-IV) approach. Our results demonstrate that FISP is associated with an increase in use of agricultural inputs (fertilizer) and boosts crop production. In addition, there are positive impacts on the likelihood that households sell maize, the crop targeted specifically by the program, and operate non-farm enterprises. Recipient households also purchase more vegetables on the market and consume more cereals from the crops they produce themselves. The evidence from this study highlights the main pathways through which an agricultural policy shapes short-term hunger and child nutritional outcomes.

Keywords Agriculture · Nutrition · Pathways · Malawi · Inputs · FISP

1 Introduction

Child undernutrition continues to be widespread around the world, especially in low-income countries, where economies are largely driven by agriculture. Since these countries have a large proportion of the population involved in agriculture and a high prevalence of undernutrition, programs that simultaneously improve agriculture and nutrition outcomes can be highly cost-effective. Indeed, agricultural policies have the potential to impact both total food production as well as food quality and diversity, thereby shaping nutritional status. However, important questions remain as to the mechanisms through which agricultural policies actually affect nutrition outcomes. Understanding these pathways is important for the design of effective nutrition-sensitive agriculture interventions (Ruel et al., 2018; van den Bold et al., 2021; Timler et al., 2020).

In this study, we seek to understand the pathways through which an agricultural policy is able to positively impact child nutritional status. A previous investigation into the Malawian

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Government sponsored Farm Input Subsidy Program (FISP), a program that provides households with vouchers for the subsidized purchase of fertilizers and maize seeds, demonstrates that children under age five years in beneficiary households have a statistically significant higher weight-for-age, weight-for-length/height and body mass index than their counterparts in non-beneficiary households (Harou, 2018).[1] Our analysis first tests whether this relationship continues to hold in subsequent years as Malawi's subsidy program starts to taper down, and shows that the positive effects of the FISP subsidy on child nutrition outcomes persist. We then seek to understand the main drivers through which FISP brings about these effects on child nutrition. Specifically, we provide evidence for three pathways. We examine the crop production and diversity channel by identifying program impacts on input use, crop diversity, livestock ownership and crop production. Subsequently, to understand the relevance of the income channel in the FISP context, we look at crop sales and non-farm enterprises, as well as household consumption of purchased (and self-produced) foods. Finally, we probe non-income dimensions by investigating women's empowerment and the health environment. We note that we only begin to explore these different mechanisms independently and do not attempt to estimate the magnitude of each pathway as one could with mediation analysis (Daniel et al., 2015). Further work is needed in this area to decipher the exact contributions of the channels we explore here and/or the role of other potential channels.

For our analysis, we use panel data from the World Bank's Malawi Integrated Household Survey (which is part of the Living Standards Measurement Study program) collected over four rounds in 2010, 2013, 2016 and 2019. Combining household fixed effects with an instrumental variable approach (FE-IV), we identify suggestive evidence of the way in which FISP is likely to shape child nutrition and the different potential pathways through which these impacts might emerge. Our results show that receiving FISP vouchers increases the likelihood that households use inorganic fertilizer. Estimates also show that FISP increases total crop production as well as maize production. Furthermore, we find that households who receive FISP vouchers are more likely to sell the maize crop they produce and they are also more likely to operate non-farm enterprises. Our investigation into food consumption from different sources indicates that households consume more vegetables from purchases and more cereals from their own produce when benefitting from the subsidies compared to when they are not benefitting. Finally, we do not find that FISP systematically enhances female empowerment within the household, nor do we detect any effects on access to health goods and services. In summary, we find that Malawi's FISP is likely affecting child nutrition through the crop production and income channels, whereby program households are increasing their fertilizer use, crop production, crop sales and engagement with non-farm enterprises; they are also consuming more of certain categories of foods, primarily cereals.

Our study makes valuable contributions. We examine a comprehensive set of factors that can potentially mediate an agricultural policy's effects on child nutrition. The evidence from our investigation is thus an important addition to the literature linking agriculture and nutrition. Furthermore, we identify factors facilitating developments in child nutrition in a context with high levels of undernutrition—in our study context of Malawi, stunting and underweight rates are high at 39 and 12 percent, respectively (FAO, 2015; Global Nutrition Report, 2020). Our investigation is thus able to point to the channels (such as household productive activity) that can be shaped by agricultural as well as non-agricultural policies in order to enhance child health in such settings.

The rest of the paper is organized as follows. Section 1 describes the conceptual framework we use to examine agriculture-nutrition linkages and Section 2 reviews the FISP program we study. Sections 3 and 4 describe the data and methods. We lay out our results in Section 5 and conclude with a discussion in Section 6.

2 Background: agriculture-nutrition linkages

There has been significant evidence generated from different settings over the past two decades linking agriculture to nutrition. For example, several studies show that child nutrition is affected by agricultural growth (Mary et al., 2020; Passarelli et al., 2020; Headey, 2013; Headey & Hoddinott, 2016; Euler et al., 2017; Pauw & Thurlow, 2011), while others demonstrate that nutrition responds to agricultural diversity (Headey & Masters, 2019; Sibhatu & Qaim, 2018). Some investigations examine links between nutrition and price shocks, food affordability and market access (Block et al., 2004; Chege et al., 2015; Gomez & Ricketts, 2013; Headey & Alderman, 2019; Headey et al., 2019). Other studies show how labor participation and practices in agriculture (practices ranging from pesticide-use to female decision-making) shape the health and nutrition of household members (Brainerd & Menon, 2014; Cunningham et al., 2015; Headey & Masters, 2019; Higgins & Alderman, 1997; Sraboni et al., 2014). The diversity of these studies highlights the complexity of the agriculture-nutrition nexus.

To help clarify how agriculture might affect nutrition, several studies offer conceptual frameworks defining different

[1] The study also shows that FISP households, both those with and without children, consume cereals, nuts, vegetables, meat and fruits on more days of the week than non-FISP households.

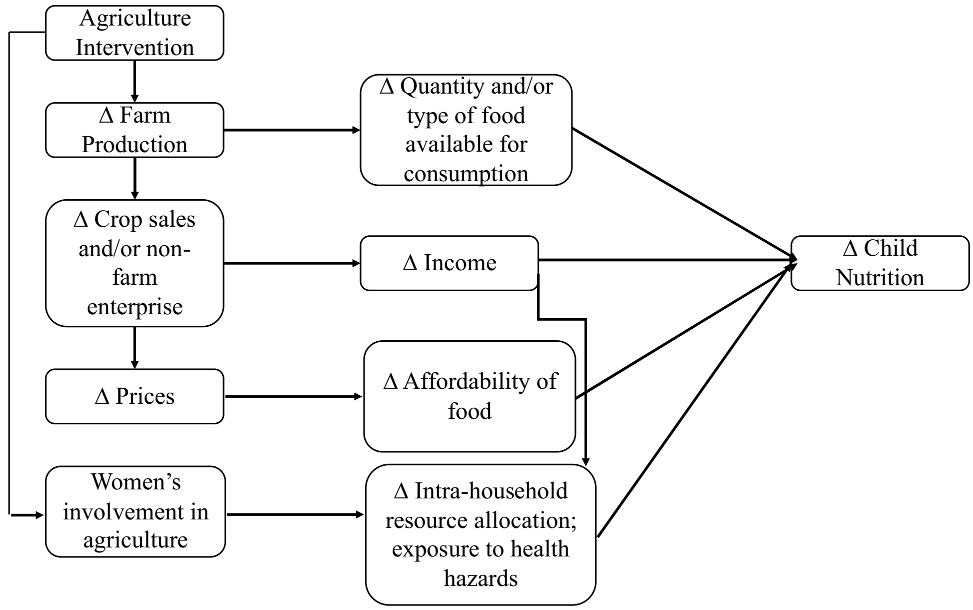

Fig. 1 Potential Agriculture-Nutrition Pathways

possible pathways (Haddad, 2013; Headey & Hoddinott, 2016; Headey & Masters, 2019; Headey et al., 2012; Hoddinott, 2012; Kadiyala et al., 2014; Pinstrup-Anderson, 2012; World Bank, 2007). These frameworks all tend to include four main themes, which we highlight in Fig. 1. First, total crop production affects the availability of food for consumption within the household both in terms of the quantity of food produced and the type of food. Indeed, past studies have found, for example, a positive association between crop diversification and dietary diversification (Kadiyala et al., 2014). Second, the amount of crop produced can increase the real income of households through sales of surplus crops, and thus boost food and non-food expenditures, such as spending on health care and sanitation. Farm activities can also shape income generated through non-farm enterprises—farming can be labor intensive, thereby reducing participation in and income from other activities; conversely, the income generated from crop sales might leave household members with more time (and capital) for other productive activities. As aforementioned, income growth is associated with an improvement in nutrition status (Haddad, 2013; World Bank, 2007). Third, agriculture can affect nutrition through non-income dimensions like female involvement and empowerment in intra-household decision-making. For example, Bhagowalia et al. (2012) find that economic recessions and income volatility increase female labor force participation, having detrimental effects on health care and child survival. Finally, an increase in production can increase the local supply of foods, reducing real food prices. Indeed, lowering of food prices can provide less expensive access to food and nutrition, especially to net buying households. In this study, we examine each of these linkages except for the fourth pathway due to data limitations on food prices.

3 The Malawi Farm Input Subsidy Program (FISP)

Targeted input subsidy programs have been widely leveraged for the past two decades to address the underuse of agricultural inputs such as inorganic fertilizers and improved seeds in much of sub-Saharan Africa; the farmers who are targeted are those expected to benefit the most from such subsidies (Jayne & Rashid, 2013; Kelly et al., 2011). According to the World Bank's Living Standards Measurement Study–Integrated Surveys on Agriculture, the data we use in this study and that we describe below, the Malawi Farm Input Subsidy Program (FISP) annually distributed and sold discounted fertilizers, seeds and pesticides to approximately 14–49% of households in the country. Beneficiaries received vouchers for 50 kg (kg) of basal fertilizer and 50 kg of urea fertilizer—the government covered 64–95% of the market price of these inputs—with the vouchers being redeemable at officially designated outlets. In some years, the program also provided additional inputs like maize, cotton, legume seeds and other fertilizers and pesticides (Lunduka et al., 2013). In an effort to cut program costs, the government reduced the number of recipient households starting in the 2016–2017 agricultural season to approximately 900,000 recipients, down from between 1.3–2.2 million recipients in previous years (World Bank, 2017). They also lowered the subsidy to about 80% of the retail value of fertilizer. In the same year, to increase the efficiency of the program, the government of Malawi outsourced the selling and management of the distribution of fertilizer vouchers to the private sector (Nkhoma, 2018; World Bank, 2017). Since 2020, the Affordable Inputs Programme (AIP) has replaced FISP with the same objectives – reducing poverty and food insecurity. Like FISP, AIP distributes and sells fertilizer and seed vouchers, but it is meant to account for some of the lessons learned from FISP regarding, for example, the timing of fertilizer distributions, improved targeting to the farmers who can most benefit from subsidies, and increased efficiency in the distribution and redemption of vouchers (Kenamu & Thunde, 2020). The degree to which these improvements have been implemented and their effects are yet to be determined.

Under the FISP program, vouchers were distributed annually to communities in a step-wise manner. First, the Ministry of Agriculture and Food Security allocated vouchers to districts based on the area of land under cultivation. Next, traditional authorities, district development committee authorities and other authorities distributed coupons across villages within districts. At the final stage, village leaders identified beneficiary households, though in later years, some villages conducted beneficiary selection through community-based targeting in open forums (Ricker-Gilbert et al., 2011; Holden & Lunduka, 2012; Chirwa & Dorward, 2013; Lunduka et al., 2013; Chibwana et al., 2014).

While FISP broadly aimed to support poor land-owning households in rural areas, the specific eligibility criteria used to distribute vouchers changed over time. For example, in 2006–2007, the program targeted full-time smallholder famers unable to afford unsubsidized fertilizer; in 2009–2010, other factors were considered, for example, whether households were made up of resource-poor village residents owning and cultivating land, had guardians caring for physically challenged individuals, or were vulnerable households, such as those headed by elderly persons, children or women. Unofficial criteria were also often used to identify beneficiary households, with recipients selected based on their relationship with village leaders and their status in the village. In fact, investigations into FISP's implementation and impacts have highlighted that the program has not necessarily reached farmers most in need. Rather, it has catered to wealthier households, those that have larger land and livestock assets, and male-headed households (Ricker-Gilbert et al., 2011; Holden & Lunduka, 2012; Chirwa & Dorward, 2013; Lunduka et al., 2013; Chibwana et al., 2014; Kilic et al., 2014).

FISP has garnered significant attention with many studies evaluating different aspects of the program. While national statistics reveal record maize production levels since the inception of FISP (Denning et al., 2009; Lunduka et al., 2013), those production figures fall short when compared to evidence from studies on household-level and satellite-derived crop production estimates; the latter point to positive but smaller program benefits (Messina et al., 2017; Ricker-Gilbert & Jayne, 2011). Some researchers have found positive associations between FISP and both organic and inorganic fertilizer use (Chibwana et al., 2014; Holden & Lunduka, 2012), but, as aforementioned, not necessarily between FISP and productivity (Messina et al., 2017; Ricker-Gilbert & Jayne, 2011). Some studies have also examined the effect of FISP on the commercial demand for inorganic fertilizer and improved seeds, finding a crowding out effect especially if targeting does not adequately reach the poor (Mason & Ricker-Gilbert, 2013; Ricker-Gilbert et. al., 2011). Holden and Lunduka (2012) examine how the demand for inputs differ between harvest versus planting time, finding that farmers have a greater demand during the latter. Chibwana et al. (2012) find positive correlations between FISP participation and growing maize and tobacco while Kankwamba et al. (2018) find FISP beneficiaries increase their agricultural diversification. Koppmair et al. (2017) find positive associations between FISP and the adoption of natural resource management technologies. More recent work has examined the role of FISP and risk, finding that FISP helps offset the adverse effects of rainfall shocks (Ajefu et al., 2021) and that FISP and drought lead to an increase in adoption of drought tolerant maize varieties (Katengeza et al., 2019). Mwale et al. (2022) find that FISP helps poorer, smaller farmers increase their household per capita consumption. Pace et al. (2018) find beneficial synergies between FISP and a social cash transfer programme, while Frempong (2022) finds that FISP is associated with an increase in child labour, especially in uneducated, male-headed households. Finally, beginning with Harou (2018), several studies have examined the effect of FISP on household food security, consumption, dietary diversity and child nutrition (Matita et al., 2022; Tione et al., 2022). While most studies find a beneficial association, Walls et al. (2023), who use qualitative methods, find no significant impact of FISP on food choices and dietary diversity. This paper contributes to this broad literature evaluating FISP, and more specifically the evidence base examining the effects of the program on household consumption and child nutrition. In particular, we aim to begin to unravel the mechanisms through which an agricultural input subsidy policy, FISP, might lead to a change in child nutrition outcomes.

4 Data

The data we use is from the Integrated Household Survey (IHS) Program in Malawi, which started collecting panel data for a sample of households in 2010–11.[2] The baseline

[2] The program is implemented by Malawi's National Statistical Office with assistance from the Living Standards Measurement Study–Integrated Surveys on Agriculture, a World Bank household survey program.

sample of 3,246 households in 204 enumeration areas was selected to be representative at the national- and at the rural/urban-levels. The first follow-up survey was conducted in 2013. Importantly, the program tracked and incorporated into the sample any new households formed by members leaving the households they lived in during the initial 2010–11 round. Subsequent surveys were conducted in 2016–17 and 2019–20, but given budget and logistical constraints, these rounds covered only the households in 102 of the baseline enumeration areas.[3] At final follow-up in 2019, there were 3,178 households surveyed by the Malawi IHS program; these households stemmed from 1,491 of the households included in the baseline sample. The long-term panel that we use includes only those households that were interviewed in all four survey rounds of the IHS, with households linked to the original household they belonged to at baseline (that is, in 2010).[4] Given our focus on agriculture, which is mostly limited to rural areas, we further restrict the sample for our analysis to the rural households of the long-term IHS panel. Our final sample contains 5,250 household-wave level observations, originating from 1,040 of the households that were initially surveyed in 2010–11.[5]

At each survey round, the IHS administered separate questionnaires to collect information on household characteristics, agricultural activities, and fisheries.[6] Here we use data collected through the household and agriculture modules. The main variable in our analysis, the covariate of interest, captures household receipt of coupons for subsidized farm inputs. This measure is an indicator variable for whether or not households received at least one subsidy coupon for inputs such as nitrogen-phosphorus-potassium fertilizer, urea, or maize seed for the most recent rainy season – the main harvest season in Malawi.

The outcome variables we examine relate to child nutrition and to the three potential agriculture-nutrition pathways described above in Fig. 1. The IHS surveys measured all children aged five years and below for height and weight. We have a total of just over 3,400 child-wave level observations in the panel, with all children linked to 891 of the households measured by the IHS Program at baseline. Using these measurements and WHO child growth standards, we construct anthropometric z-scores for the following child nutritional outcomes—weight-for-height (wasting), height-for-age (stunting), weight-for-age (undernutrition) and body mass index (BMI)-for-age (World Health Organization, 2006). The z-scores indicate where children stand in the distribution of the relevant health measure in a population of healthy children—for example, a weight-for-height (WHZ) z-score of +1 means that a child is one standard deviation above the median weight of children of the same height in the reference population. WHZ reflects current nutritional status and can be used to assess the effects of short-term changes in nutrition. Height-for-age z-scores (HAZ) capture cumulative linear growth and can point to chronic malnutrition. The weight-for-age z-score (WAZ) is a composite of WHZ and HAZ and can be used to monitor growth and to gauge temporal changes in the extent of malnutrition. BMI, which is defined as weight in kilograms divided by the square of height in meters, is a measure of malnutrition (both under- and over-nutrition) (O'Donnell et al., 2007).

The pathways we focus on relate to the three sets of agriculture-nutrition linkages described in the Introduction. Given the data collected by the IHS surveys, we do our best to capture these different channels. First, to measure FISP's influence on household crop production and diversity, we probe effects on agricultural input use and practices (fertilizer and seed use, number of crop varieties grown and livestock ownership), and crop production.[7, 8] For crop-related outcomes, we present results for all crops together and also separately for maize since Malawi's FISP package has consistently distributed fertilizer and seed specifically for maize (Chirwa & Dorward, 2013). Note that all the agricultural measures we look at in this analysis pertain to the rainy season, which is the main farming season in Malawi. Second, to examine whether FISP has affected income, we examine crop sales as well as household non-farm enterprise ownership and sales. Information on household enterprises apply to the 12 months before the survey. Since any FISP-induced changes to production and agricultural earnings could alter households' reliance on their own production for food and/or their ability to purchase food items on the market, we also investigate the effect of FISP on food consumption over the past week from different sources—own-production and

[3] These follow-up samples were selected such that reliable estimates could be obtained for rural and urban Malawi (Republic of Malawi National Statistical Office, 2017).

[4] Data is available from https://microdata.worldbank.org/index.php/catalog/3819.

[5] We drop 214 household-wave level observations because there are missing data for the control variables that we use (described later in the Section 5).

[6] A fourth questionnaire, a community survey, was administered to community representatives. The 2016–17 survey round also administered an individual questionnaire to collect information on assets and food security.

[7] Among fertilizer inputs, we restrict our attention to inorganic fertilizer which is the most commonly used fertilizer—78 percent of farming household used this input. In contrast, 28 percent used organic fertilizer and six percent used pesticides/herbicides.

[8] Fertilizer and seed quantities are in kilogram (kg) and are transformed using the inverse hyperbolic sine transformation since these variables are positively skewed. Crop production is measured in kilogram (kg) and we log the positive production values to normalize the distribution (production estimates are positively skewed).

purchases. Third, we examine a series of more downstream pathways. To understand whether the program shaped female empowerment, we probe whether the female household head or female spouse of the household head owned different types of assets (land, a bank account and livestock) and whether she contributed towards farming decisions (related to cropping activities such as crop choice, the use of household crop produce, and the use of earnings from crop sales).[9] Since FISP could impact household access to nutrition-relevant goods and services, we also investigate different health outcomes (recent illness and health seeking behaviors) as well as housing characteristics (construction materials of the household dwelling, and water and sanitation).

Table 9 in the Appendix defines all the outcome variables we explore. Note that all these measures are expected to capture household conditions in the period after the input coupons were received – for example, total crop production is realized only at the end of the harvesting season and child anthropometry is measured at the time of the survey – and so any relationship we observe between household receipt of input subsidies and these variables is likely to be directed from the subsidies towards the other measures.

Table 1 presents summary statistics on all outcome variables separately for households when they received farms input coupons and for when they did not. Households do seem to do significantly better on several measures when they receive subsidized inputs – for example, they are more likely to use inorganic fertilizer. However, simply contrasting outcomes in this way is likely to lead to biased results since households that never receive input coupons are expected to be different from those that receive coupons at some point during the study period. In the next section, we describe the methods we use to plausibly overcome such issues of bias.

5 Methods

We are interested in identifying the effects of household FISP receipt on child nutritional outcomes and on a range of potential agriculture-nutrition pathways. As discussed in the Background section above, various factors are likely to shape whether or not a household benefits from FISP in any given year. For example, socially connected households tend to have a higher likelihood of securing coupons than less connected households. Alternatively, household location could play a determining role, perhaps with more remote households being excluded from the program. These factors—household networks and location—are also likely to shape the outcomes we care about, such as agricultural production. Since program beneficiaries and non-beneficiaries are expected to be systematically different, attempts to approximate FISP impacts by comparing these two groups are likely to yield biased results.

To overcome such biases, we employ a fixed effects-instrumental variable (FE-IV) approach. The fixed effects we use are at the household-level, and so essentially, we are comparing outcomes in households when they benefit from the program to outcomes in the *same* household at another time when they do not benefit.[10] Importantly, the fixed effects allow us to control for all household characteristics that are time-invariant, characteristics that are observed (for example, assets that remain constant over time) as well as those that are unobserved (for example, the inherent farming acumen of the household head). The scope and targeting of FISP has changed tremendously over the decade that we cover in our analysis, and so we combine the household fixed effects with an IV strategy in which we leverage the temporal variation in the geographic allocation of FISP as an instrument for household-level receipt of the program.[11] Specifically, we use the proportion of households in a district receiving farm input coupons during a year to instrument for whether or not a household benefitted from the program that same year.[12] The average district-level proportion of households benefitting from FISP is 0.49, 0.37, 0.29 and 0.14 in 2010–11, 2013, 2016–17 and 2019–20, respectively; the temporal pattern clearly points to the winding down of the program over time. Our use of the proportion measure as an IV for household receipt of FISP draws upon instruments that have been used in previous analyses of FISP (Harou, 2018; Mason & Ricker-Gilbert, 2013). Note that our IV is exogenous to households and to the village-level process determining the selection of program beneficiaries. This makes it unlikely that it is correlated with time varying household

[9] It would have been ideal to use the Women's Empowerment in Agriculture Index (Malapit et al., 2019) to investigate the impact of FISP on women's role in the household. However, we do not have the data for all the indicators used to construct this composite measure. Note, though that the WEAI does incorporate the information we examine—women's input in productive decisions, and their ownership of land and assets.

[10] Note that all households stemming or splitting off from a household at baseline are still compared to outcomes for the original household in previous rounds.

[11] An IV approach requires a variable, known as the instrument that shapes the potentially endogenous covariate of interest and that influences the outcome(s) only through this variable (Wooldridge, 2010). The instrument carves out the plausibly exogenous variation in the covariate of interest and allows for the identification of plausibly causal effects.

[12] Results are essentially the same when we conduct the estimation using the leave-one-out instrument - that is, when we instrument for household receipt of FISP with the average proportion of households benefiting from FISP after excluding that household from this average. These results are available upon request.

Table 1 Agricultural-nutrition linkages: Differences across households when they benefit and do not benefit from farm input coupons

	Households not receiving input coupons	Households receiving input coupons	Difference significant
Used any inorganic fertilizer	0.64	0.95	***
Used any inorganic fertilizer for maize	0.68	0.94	***
Quantity of inorganic fertilizer used (in kilogram (kg))	64.78	104.12	***
Quantity of inorganic fertilizer used (kg) for maize	52.67	84.13	***
Quantity of seed used (in kg)	28.60	31.64	**
Quantity of seed used (in kg) for maize	12.00	13.31	**
Number of crops grown	2.67	2.85	**
Owns livestock	0.75	0.76	
Quantity of total crop production (in kg)	766.72	1,023.63	***
Quantity of maize production (in kg)	516.06	659.56	***
Any crop sales	0.50	0.57	**
Any maize crop sales	0.17	0.20	**
Crop sales value (in Malawian Kwacha (MK))	72,558.93	62,448.54	
Maize crop sales value (in MK)	29,582.93	21,849.80	**
Owns any household enterprise	0.29	0.27	
Value of total sales during the last month of operation (in MK)	42,100.46	19,213.82	***
Food consumption from purchases (in kg)			
Cereal, grains and cereal products	4.48	3.00	**
Roots, tubers and plantains	1.92	1.83	
Nuts and pulses	0.54	0.52	
Vegetables	2.66	2.55	
Fruits	0.45	0.52	
Meat, fish and animal products	0.97	0.80	
Milk and milk products	0.17	0.08	**
Food consumption from own-production (in kg)			
Cereal, grains and cereal products	7.86	11.54	***
Roots, tubers and plantains	1.06	1.51	**
Nuts and pulses	0.53	0.77	**
Vegetables	1.28	2.61	***
Fruits	0.36	0.63	***
Meat, fish and animal products	0.25	0.28	
Milk and milk products	0.02	0.05	
Woman owns land	0.75	0.73	
Woman currently has a bank account	0.15	0.17	
Woman owns livestock	0.80	0.80	
Woman makes decisions on cropping activities	0.87	0.86	
Woman makes decisions on the use of crop output	0.85	0.83	*
Woman keeps/decides what to do with earnings from crop sales	0.78	0.76	
At least one household member suffered from illness or injury in previous week	0.69	0.68	
Household sought professional care for illness or injury	0.67	0.66	
Child member (<= 5 years) participates in a nutrition program	0.07	0.09	
Child member (<= 5 years) participates in an under-five clinic	0.73	0.73	
Wall of dwelling is made of sturdy materials	0.85	0.84	
Roof of dwelling is made of sturdy materials	0.37	0.34	
Floor of dwelling is made of sturdy materials	0.19	0.15	*
Dwelling has toilet	0.65	0.69	**
Main source of drinking water is piped water into dwelling, yard or plot	0.02	0.01	***

Table 1 (continued)

	Households not receiving input coupons	Households receiving input coupons	Difference significant
Child body mass index z-score	0.30	0.44	*
Child weight-for-age z-score	-0.37	-0.37	
Child weight-for-height z-score	0.18	0.33	**
Child height-for-age z-score	-0.91	-1.09	**
Observations	3,363	1,887	

The standard errors used for these tests are clustered at the district-level. Statistically significant mean differences across groups based on Wald tests are represented by: *$p<0.1$; **$p<0.05$; ***$p<0.01$

characteristics that shape household receipt of FISP as well as household-level outcomes. Nonetheless, despite our attempt to reduce the bias by combining FE with IV, it is possible that remaining biases exist, e.g., by not controlling for time-varying characteristics like agricultural labor inputs, so our point estimates should be interpreted with caution.

It is also important to note that an IV approach allows us to estimate a local average treatment effect (LATE) which holds only for those whose treatment status is impacted by the instrument (Imbens & Angrist, 1994).[13] Further, given that we focus on a subset of households covered by Malawi's IHS Program (those that show up in each survey round between 2010 and 2019), our sample is not nationally representative. Accordingly, the estimates we identify are unlikely to be widely generalizable, but would allow us to make some inferences about the potential efficacy of FISP among a sample of households for whom we have FISP receipt and other data over time.

Our FE-IV strategy requires that we conduct our estimation in two stages. The first stage identifies the effects of the instrument on household receipt of FISP coupons:

$$FISP_{idt} = \alpha_1 Z_{dt} + \alpha_2 X_{idt} + \mu_i + \varepsilon_{idt} \quad (1)$$

where $FISP_{idt}$ captures whether household i in district d is a coupon beneficiary in year t. Z_{dt} is the instrumental variable we describe above, X_{idt} is a vector of controls (survey round indicators, region-specific linear time trends, household size and dependency ratio, and household head characteristics—age, sex, marital status and years lived in village of residence),[14] μ_i are household fixed effects (indicator variables for each household in the study sample), and ε_{idt} is the error term.

The second stage identifies the potential effect of household FISP receipt on any outcome of interest:

$$Y_{idt} = \beta_1 Pred\_FISP_{idt} + \beta_2 X_{idt} + \mu_i + \nu_{idt} \quad (2)$$

where Y_{idt} is an outcome for household i in district d in year t. As discussed in Section 4, we explore various outcomes such as child HAZ, household use of inorganic fertilizer and crop production (see Table 9 in the Appendix for the comprehensive list of all outcomes along with definitions). $Pred\_FISP_{idt}$ is predicted FISP receipt from (1) and ν_{idt} is the error term. All other variables are the same as in (1). β_1 approximates the impact of FISP and is the coefficient of interest. We cluster standard errors at the district-level in all specifications. Finally, since we are conducting multiple tests for each hypothesized channel, we also implement a multiple-test adjustment of p-values within each mediator family for which at least one unadjusted p-value indicates statistical significance and present corrected critical p-values (known as q-values).[15]

[13] One way in which the LATE might be different from the average treatment effect (ATE) is if the instrument pushes a select group into the treatment. As discussed above, FISP might largely benefit wealthier households, but when the scope of the program in a region expands, less wealthy households might come to be enrolled. If this is the case, the marginal household whose treatment status would be affected by the instrument might have a high potential to benefit from the subsidy and therefore experience higher impacts (the LATE would then be larger than the ATE). Note though that we are unable to conclusively determine the characteristics of those whose treatment status is determined by the instrument and indicate how the LATE might compare to the ATE.

[14] Since farm input subsidies can plausibly shape a wide range of household characteristics (for example, by boosting income), we use only a sparse list of household-level controls so as to not introduce bias into the estimates we identify. Note, however, that the household fixed effects account for all time-invariant household characteristics. Dependency ratio is the ratio of number of household members 0–14 years and 65 years and above to the number of household members aged 15–64 years. When examining child nutritional outcomes, we also include the following controls: child gender and age indicators, as well as mother's characteristics—age, marital status, literacy and school attendance. Note, we use a linear model to reduce potential bias from having a low number of time periods and high number of fixed effects (what is known as the "incidental parameters problem") (Neyman & Scott, 1948; Lancaster, 2000).

[15] We implement the Simes multiple hypothesis test adjustment procedure using the STATA command *qqvalue* (Newson, 2010).

Table 2 Impacts of Malawi's Farm Input Subsidy Program (FISP) on child nutrition

Dependent variable:	(1) Weight-for-height z-score	(2) Height-for-age z-score	(3) Weight-for-age z-score	(4) Body mass index z-score
Household received input coupon(s)	0.868**	0.281	0.840***	0.922*
	(0.429)	(0.728)	(0.311)	(0.502)
q-value[a]	0.086	0.700	0.028	0.088
Observations	3,456	3,455	3,481	3,449
Number of households	888	889	891	887
Dependent variable mean for households not receiving coupons	0.185	-0.903	-0.373	0.302
First stage instrument F-statistic	52.25	47.27	55.04	51.48

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. All specifications control for child age and sex, survey wave fixed effects, region-specific linear time trends, household size, dependency ratio, household head characteristics (age, sex, marital status and years lived in the village of residence) and mother's characteristics (age, marital status, literacy and education). Standard errors presented in parentheses are clustered at the district-level. *$p<0.1$; **$p<0.05$; ***$p<0.01$. [a]These are the corrected critical *p*-values obtained following multiple-hypothesis test adjustments (for outcomes in this table) using the Simes procedure

6 Results

We present estimates of FISP's impact on child nutritional outcomes in Table 2 and on potential agriculture-nutrition linkages in Tables 3, 4, 5, 6, 7 and 8. At the bottom of every column, we provide the F-statistic for the instrumental variable from the first stage. All F-statistics are well above 10, which indicates that we have a strong instrument (Bound et al., 1995; Staiger & Stock, 1997).[16] We include results from the first stage for the full sample in Table 10 in the Appendix. The estimate on the instrument, the proportion of households in the district receiving input coupons, points to a positive relationship between household FISP receipt and the probability of voucher receipt.

Moving to the main results, in Table 2, we document that FISP had positive and statistically significant impacts on child WHZ (column 1), WAZ (column 3) and child BMI (column 4). There are no impacts on HAZ (column 2), an outcome that reflects long-term conditions and is therefore difficult to change.

Table 3, Panel A shows that program subsidies increase the likelihood of inorganic fertilizer use (column 1). Moreover, we see in column 2 that receiving (a) coupon(s) is associated with a higher likelihood of inorganic fertilizer use specifically for maize crops. We also find that the program increases the amount of inorganic fertilizer that households apply to their crops overall and to maize crops (columns 3 and 4). In other words, FISP appears to impact the extensive margin as well as the intensive margin of inorganic fertilizer use. We do not detect program impacts on any of the other agricultural inputs and agricultural diversity measures we examine in this table (Panel B)—seed use, number of crops grown and livestock ownership. This is not surprising given that FISP predominantly distributed maize seed and fertilizer formulated for maize.

Upon probing household crop production in Table 4, we find evidence of FISP-generated increases in the production of all crops (column 1) and maize crops (column 2).[17]

Turning to crop sales (Table 5, Panel A), we find no effect on all crop sales (columns 1 and 3). When looking specifically at maize, we find a higher incidence of maize crop sales among households when they benefit from FISP (column 2), but there are no impacts on earnings from maize crops (column 4). As we showed earlier, households who received a subsidy increased yields, which likely increased their likelihood of selling some of that production in the market. Alternatively, it is also possible that households may sell maize from their stocks, not from new production. Indeed, given the price volatility observed over a year due to seasonality, farmers may hold onto harvest to sell at a later time when prices are higher (Burke et al., 2018). We suspect that the lack of result on the value of maize sales results from the noise in the data, which is apparent with the large standard errors. In

[16] The only exception is the F-statistic in Panel A, column 4 of Table 5.

[17] As we show in Table 11 in the Appendix, estimates obtained for the quantity of fertilizers used and quantity of harvests are similar when we measure these quantities in kg per acre.

Table 3 Impacts of Malawi's Farm Input Subsidy Program (FISP) on agricultural inputs and diversity

Panel A: Inorganic fertilizers				
	(1)	(2)	(3)	(4)
Dependent variable:	Used any inorganic fertilizer	Used any inorganic fertilizer for Maize	Quantity of inorganic fertilizer used (in kilogram (kg))[a]	Quantity of inorganic fertilizer used (in kg) for Maize[a]
Household received input coupon(s)	0.270***	0.252***	1.432***	1.288***
	(0.082)	(0.093)	(0.383)	(0.388)
q-value[b]	0.003	0.013	0.001	0.003
Observations	5,250	4,953	5,250	4,953
Number of households	1,040	1,020	1,040	1,020
Dependent variable mean for households not receiving coupons	0.644	0.680	2.996	3.090
First stage instrument F-statistic	207.75	184.17	207.75	184.17
Panel B: Seeds			*Panel C: Other agricultural practices*	
	(1)	(2)	(3)	(4)
Dependent variable:	Quantity of seed used (in kg)[a]	Quantity of seed used (in kg) for Maize[a]	Number of crops grown	Owns livestock
Household received input coupon(s)	0.154	-0.229	0.265	0.096
	(0.384)	(0.242)	(0.442)	(0.123)
q-value[b]	0.688	0.550	0.627	0.581
Observations	5,243	4,984	5,179	3,925
Number of households	1,039	1,025	1,032	1,025
Dependent variable mean for households not receiving coupons	28.794	2.814	2.669	0.750
First stage instrument F-statistic	3.395	187.80	215.06	123.93

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. All specifications control for survey wave fixed effects, region-specific linear time trends, household size, dependency ratio and household head characteristics (age, sex, marital status and years lived in the village of residence). Standard errors presented in parentheses are clustered at the district-level. $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$. [a]We look at the inverse hyperbolic since transformation of these measures. [b]These are the corrected critical *p*-values obtained following multiple-hypothesis test adjustments (for outcomes in this table) using the Simes procedure

Panel B of the same table, we find suggestive evidence that FISP also increases household ownership of non-farm enterprises (column 1). The business run by households while receiving input coupons are not, however, more profitable than those operated by households when they do not benefit from FISP (column 2). We conjecture that the increase in non-farm enterprises could result from the possibly higher revenue generated by increased maize crop sales which encouraged farmers to diversify into non-farm enterprises. Again, we interpret results on the value of total sales with caution since we suspect there is significant measurement error given the high standard errors.

In terms of food consumption (results presented in Table 6), we find FISP households increasing their consumption of vegetables from purchases (Panel A, column 4) and of cereals from their own production (Panel B, column 1). The coefficients for the other food categories are, however, imprecise. The food estimates observed in this table suggest that FISP is unable to facilitate access to a wide variety of food groups over the 10 years included in our analysis (2010–2019) and in fact, in results presented in Table 12 in the Appendix we do indeed fail to detect a significant program impact on household food consumption scores (FSC).[18] This result is in contrast to the positive diet

[18] We use the World Food Programme's (WFP) methodology to construct this variable, one that summarizes the frequency of consumption of different food groups and weights the report for each group with the nutritional value of that group (WFP, 2008).

Table 4 Impacts of Malawi's Farm Input Subsidy Program (FISP) on crop yields

	(1)	(2)
Dependent variable:	Logged quantity of total crop yields (kg)	Logged quantity of crop yields (in kg) for Maize
Household received input coupon(s)	0.897**	1.161**
	(0.428)	(0.454)
q-value[a]	0.036	0.021
Observations	5,113	4,865
Number of households	1,034	1,020
Dependent variable mean for households not receiving coupons	6.079	5.715
First stage instrument F-statistic	210.01	174.08

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. All specifications control for survey wave fixed effects, region-specific linear time trends, household size, dependency ratio and household head characteristics (age, sex, marital status and years lived in the village of residence). Standard errors presented in parentheses are clustered at the district-level. *$p<0.1$; **$p<0.05$; ***$p<0.01$. [a]These are the corrected critical p-values obtained following multiple-hypothesis test adjustments (for outcomes in this table) using the Simes procedure

diversity estimates found to stem from the implementation of FISP between 2010 and 2013 in Harou (2018).

Table 7 contains results for the female empowerment outcomes and Table 8 presents impacts for different measures related to health and housing. We fail to find evidence of FISP bringing about changes in any of these potential mediators. This is not consistent with past studies that have found, for example, that FISP contributed to closing the gender gap in adopting modern maize (Fisher & Kandiwa, 2014).

7 Discussion and conclusion

The current analysis examines how Malawi's Farm Input Subsidy Program (FISP), a targeted scheme designed to address the underuse of agricultural inputs in the country, is able to positively impact child nutritional outcomes such as weight-for-age and body mass index. The potential linkages between agriculture and nutrition are numerous and complex. We focus our attention on factors encompassed within three broad categories of pathways—(1) crop production and diversity, (2) income through crop sales and non-farm enterprises, and food consumption from different sources, and (3) female empowerment and the health environment.

Our study has several findings:

1. We demonstrate that households who receive a FISP voucher are more likely to use inorganic fertilizer and produce more crops, especially more maize. These results are consistent with findings from other studies. Carter et al. (2013), for example, show that voucher coupons in Mozambique increase the use of seeds and fertilizers for those who choose to redeem the vouchers. However, we find that households who receive a FISP voucher do not grow a greater diversity of crops, an agricultural practice associated with improved nutrition (Headey & Masters, 2019; Sibhatu & Qaim, 2018).
2. We find that households who receive a FISP voucher are more likely to engage in sales of maize, and also more likely to operate non-farm enterprises.
3. Consistent with Harou (2018), our analysis demonstrates that FISP recipients consume more vegetables (through purchases) and more cereals (through self-production).
4. Finally, we do not detect any significant effect of FISP on female empowerment or access to health goods and services. Fisher and Kandiwa (2014), on the other hand, demonstrate a significant gender gap in the adoption of modern maize, and find that FISP reduces this gender gap.

While we do not examine the effect of FISP on prices, Ricker-Gilbert et al. (2013) estimate the effect of fertilizer subsidies on retail maize prices in Malawi and Zambia and find that a doubling of the size of Malawi's subsidy program reduces maize prices by 1.2 to 2.5% due to the increase in crop production. These effects are minimal and are therefore not expected to account for the sizeable changes in child nutrition observed in Harou (2018) and in the current analysis.

To summarize, our results demonstrate that the impacts of Malawi's FISP on child nutrition are likely operating predominantly through the crop production and income channels —the program allows farming households to increase the use of agricultural inputs, which boosts crop production, crop sales and engagement in non-farm enterprises. This increase in productivity enables households to increase the consumption of certain nutritious foods, both from purchases and own crop production.

Our results have important policy implications. Agricultural policies aiming to increase crop production may have positive indirect effects on nutrition outcomes. In the case of a targeted input subsidy program, we show that improvements in nutrition result primarily from an increase in higher maize production and economic

Table 5 Impacts of Malawi's Farm Input Subsidy Program (FISP) on income outcomes

Panel A: Crop sales				
	(1)	(2)	(3)	(4)
Dependent variable:	Any crop sales	Any maize crop sales	Crop sales value (in Malawian Kwacha (MK))	Maize crop sales value (in MK)
Household received input coupon(s)	0.167	0.320***	-27,358.891	2,961.868
	(0.106)	(0.117)	(48,448.776)	(24,239.033)
q-value[a]	0.231	0.037	0.859	0.903
Observations	5,250	4,968	2,784	917
Number of households	1,040	1,024	891	482
Dependent variable mean for households not receiving coupons	0.505	0.171	73966.78	29606.62
First stage instrument F-statistic	207.75	199.85	62.23	4.16

Panel B: Non-farm household enterprise		
	(1)	(2)
Dependent variable:	Owns any household enterprise	Value of total sales during the last month of operation (in Malawian Kwacha (MK))
Household received input coupon(s)	0.219**	-7,390.123
	(0.111)	(23,188.411)
q-value[a]	0.145	0.900
Observations	5,250	3,132
Number of households	1,040	1,024
Dependent variable mean for households not receiving coupons	0.293	43282.09
First stage instrument F-statistic	207.75	121.03

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. All specifications control for survey wave fixed effects, region-specific linear time trends, household size, dependency ratio and household head characteristics (age, sex, marital status and years lived in the village of residence). Standard errors presented in parentheses are clustered at the district-level. *$p<0.1$; **$p<0.05$; ***$p<0.01$. [a]These are the corrected critical *p*-values obtained following multiple-hypothesis test adjustments (for outcomes in this table) using the Simes procedure

activity (crop sales and non-farm enterprise activity). The nutrition gains from FISP, however, seem to have mostly affected short-term nutrition indicators, weight-for-age and weight-for-length/height, since we did not find any significant effect on child HAZ which measures stunting and indicates a deficient growth environment. This is consistent with evidence from evaluations of nutrition-sensitive agriculture programs that show that such programs alone may be unable to reduce stunting but they can improve other outcomes (Ruel et al., 2018). The lack of impact on HAZ, however, does not indicate the subsidy program failed to improve child undernutrition because several nutrition outcomes did show improvements in this study. Indeed, many programs will have positive effects on certain health outcomes prior to improving linear growth (Leroy & Frongillo, 2019). The use of stunting to measure the success of an agriculture-based intervention or program, therefore, is not optimal. Instead, dietary intake and quality might be a better measure of agriculture program impacts (Leroy et al., 2020). If improving chronic malnutrition (height-for-age) is one of the primary policy objectives of an agricultural program, additional complementary interventions can be considered, such as those that provide mothers with nutrition information and/or enhance access to health services.

Table 6 Impacts of Malawi's Farm Input Subsidy Program (FISP) on food consumption

Panel A: Food consumption from purchases

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable: Quantity consumed in the past week from **purchases** (in kilogram (kg))	Cereals, grains and cereal products	Roots, tubers and plantains	Nuts and pulses	Vegetables	Fruits	Meat, fish and animal products	Milk and milk products
Household received input coupon(s)	-0.497	-0.713	0.451*	1.160**	-0.320	1.049	-0.456
	(3.651)	(0.767)	(0.241)	(0.472)	(0.370)	(1.489)	(0.470)
q-value[a]	0.892	0.535	0.288	0.098	0.535	0.535	0.535
Observations	5,250	5,250	5,250	5,250	5,250	5,250	5,250
Number of households	1,040	1,040	1,040	1,040	1,040	1,040	1,040
Dependent variable mean for households not receiving coupons	4.586	1.955	0.551	2.695	0.463	0.995	0.179
First stage instrument F-statistic	207.75	207.75	207.75	207.75	207.75	207.75	207.75

Panel A: Food consumption from own-production

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Dependent variable: Quantity consumed in the past week from **own-production** (in kg)	Cereals, grains and cereal products	Roots, tubers and plantains	Nuts and pulses	Vegetables	Fruits	Meat, fish and animal products	Milk and milk products
Household received input coupon(s)	14.034***	0.938	0.587	-1.792	0.646	0.350	0.094
	(4.657)	(1.373)	(0.864)	(1.890)	(0.472)	(0.247)	(0.064)
q-value[a]	0.036	0.535	0.535	0.535	0.399	0.399	0.399
Observations	5,250	5,250	5,250	5,250	5,250	5,250	5,250
Number of households	1,040	1,040	1,040	1,040	1,040	1,040	1,040
Dependent variable mean for households not receiving coupons	7.940	1.073	0.536	1.315	0.362	0.257	0.120
First stage instrument F-statistic	207.75	207.75	207.75	207.75	207.75	207.75	207.75

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. All specifications control for survey wave fixed effects, region-specific linear time trends, household size, dependency ratio and household head characteristics (age, sex, marital status and years lived in the village of residence). Standard errors presented in parentheses are clustered at the district-level. *$p<0.1$; **$p<0.05$; ***$p<0.01$. [a]These are the corrected critical p-values obtained following multiple-hypothesis test adjustments (for outcomes in this table) using the Simes procedure

Table 7 Impacts of Malawi's Farm Input Subsidy Program (FISP) on female empowerment

Panel A: Ownership			
	(1)	(2)	(3)
Dependent variable: Woman owns…	Land	Bank account	Livestock
Household received input coupon(s)	0.122	0.220	0.042
	(0.078)	(0.141)	(0.122)
Observations	4,876	4,300	2,974
Number of households	1,030	1,032	919
Dependent variable mean for households not receiving coupons	0.745	0.157	0.798
First stage instrument F-statistic	152.52	115.38	48.46

Panel B: Decision making			
	(1)	(2)	(3)
Dependent variable: Woman contributes to decisions on…	Crops to be planted, input use and the timing of cropping activities	Use of crop production	Use of earnings from crop sales/ woman keeps earnings
Household received input coupon(s)	0.019	0.080	0.258*
	(0.094)	(0.127)	(0.134)
Observations	4,263	4,193	2,785
Number of households	1,027	1,024	891
Dependent variable mean for households not receiving coupons	0.865	0.853	0.779
First stage instrument F-statistic	128.33	108.29	63.59

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. All specifications control for survey wave fixed effects, region-specific linear time trends, household size, dependency ratio and household head characteristics (age, sex, marital status and years lived in the village of residence). Standard errors presented in parentheses are clustered at the district-level. *$p<0.1$; **$p<0.05$; ***$p<0.01$

Table 8 Impacts of Malawi's Farm Input Subsidy Program (FISP) on health and housing

Panel A: Health

	(1)	(2)	(3)	(4)
Dependent variable:	At least one household member suffered from an illness or injury in the previous two weeks	Household sought professional care for illness or injury	Child participates in a nutrition program	Child participates in an under-five clinic
Household received input coupon(s)	0.176	-0.102	-0.005	0.019
	(0.124)	(0.149)	(0.148)	(0.111)
Observations	5,250	3,605	3,488	3,488
Number of households	1,040	1,015	891	891
Dependent variable mean for households not receiving coupons	0.690	0.672	0.074	0.731
First stage instrument F-statistic	207.75	106.26	55.57	55.57

Panel B: Housing

	(1)	(2)	(3)	(4)	(5)
Dependent variable:	Wall of dwelling is made of sturdy materials	Roof of dwelling is made of sturdy materials	Floor of dwelling is made of sturdy materials	Dwelling has toilet	Main source of drinking water is piped water into dwelling, yard or plot
Household received input coupon(s)	0.121	-0.015	-0.042	-0.097	-0.014
	(0.095)	(0.069)	(0.070)	(0.131)	(0.023)
Observations	5,250	5,250	5,249	5,250	5,250
Number of households	1,040	1,040	1,040	1,040	1,040
Dependent variable mean for households not receiving coupons	0.851	0.372	0.185	0.652	0.021
First stage instrument F-statistic	207.75	207.75	207.31	207.75	207.75

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. All specifications control for survey wave fixed effects, region-specific linear time trends, household size, dependency ratio and household head characteristics (age, sex, marital status and years lived in the village of residence). Additional controls used for columns 3 and 4 in Panel A include child age and sex, and mother's characteristics (age, marital status, literacy and education). Standard errors presented in parentheses are clustered at the district-level. *$p<0.1$; **$p<0.05$; ***$p<0.01$

Appendix

Table 9 Description of outcome variables

Variable	Description
Child nutrition	
Weight-for-height z-score Height-for-age z-score Weght-for-age z-score Body mass index (BMI) z-score	The following formula is used for all these outcomes: (measured value - median for reference population)/standard deviation for reference population (BMI = weight/height*height where weight is measured in kilogram (kg) and height is measured in meters)
Agricultural inputs and diversity	
Used any inorganic fertilizer	= 1 if household (HH) used any inorganic fertilizer (such as urea or diammonium phosphate) on a plot of land owned or cultivated by the HH = 0 otherwise
Used any inorganic fertilizer for Maize	= 1 if household (HH) used any inorganic fertilizer on a plot of land on which maize was the most important crop that was planted = 0 otherwise
Inverse hyperbolic sine (HIS) transformation of quantity of inorganic fertilizer used (in kg)	Total amount of inorganic fertilizer used on all plots of land
IHS transformation of quantity of inorganic fertilizer used (in kg) for Maize	Total amount of inorganic fertilizer used on all plots of land on which maize was the most important crop that was planted
IHS transformation of quantity of seed used (in kg)	Total amount of seed planted on all plots of land
IHS transformation of quantity of seed used (in kg) for Maize	Total amount of seed planted for maize on all plots of land
Number of crops grown	Number of crops planted on all plots of land (different varieties of a crop are disregarded - for example, if a HH grows local maize and hybrid maize, the HH is considered to be growing only one type of crop - maize)
Owns livestock	= 1 if HH currently owns any livestock = 0 otherwise
Household crop production	
Logged quantity of total crop production (in kg)	Logged amount of crops harvested from all plots of land
Logged quantity of crop production (in kg) for Maize	Logged amount of maize harvested from all plots of land
Income outcomes	
Any crop sales	= 1 if HH sold any crops = 0 otherwise
Any maize crop sales	= 1 if HH sold any maize = 0 otherwise
Crop sales value (in Malawian Kwacha (MK))	Total value of all crop sales
Maize crop sales value (in MK)	Total value of all maize sales
Owned any household enterprise	= 1 if HH has owned any enterprises (such as a trading business on a street/market or a restaurant) over the past 12 months = 0 otherwise
Value of total sales during the last month of operation of the household enterprise (in MK)	Value of total sales of products, goods or services of all HH enterprises during the last month of operation (restricted to HHs that owned any enterprise during the past 12 months)
Food consumption	
Quantity consumed in the past week from purchases (in kg):	Total quantity consumed in the past week from HH purchases (presented separately for different food groups such as 'cereals, grains and cereal products' and 'nuts and pulses')
Quantity consumed from own-production (in kg):	Total quantity consumed in the past week from HH own-production (presented separately for different food groups such as 'cereals, grains and cereal products' and 'nuts and pulses')
Female empowerment[a]	
Woman owns land	= 1 of woman owns land or is listed on land title or holds use rights to land = 0 otherwise (restricted to households owning land)

Table 9 (continued)

Variable	Description
Woman currently has a bank account	= 1 if woman owns account at a bank, credit union, micro-finance institution, post office, village savings organization or another financial institution = 0 otherwise
Woman owns livestock	= 1 if woman owns livestock = 0 otherwise (restricted to households owning livestock)
Woman makes decisions on cropping activities	= 1 if woman contributes to decisions on crops to be planted, input use and the timing of cropping activities = 0 otherwise (restricted to households owning and/or cultivating land)
Woman makes decisions on the use of crop output	= 1 if woman contributes to decisions on the use of crops = 0 otherwise (restricted to households producing crops)
Woman keeps/decides what to do with earnings from crop sales	= 1 if woman contributes to decisions on the use of earnings from crop sales/woman keeps earnings = 0 otherwise (restricted to households with any crop sales)
Health and housing	
At least one household member suffered from an illness or injury in the previous two weeks	= 1 if any household member has suffered from an illness or injury during the past two weeks = 0 otherwise
Household sought professional care for illness or injury	= 1 if HH sought professional care (for example, from a government or private health facility) for an illness or injury during the past two weeks = 0 otherwise (restricted to households who had any illness or injury during the past two weeks)
Child participates in a nutrition program	= 1 if child's mother/guardian reports that child participates in any nutrition program = 0 otherwise (defined for children aged five years or below)
Child participates in an under-five clinic	= 1 if child's mother/guardian reports that child participates in any under-five clinic = 0 otherwise (defined for children aged five years or below)
Wall of dwelling is made of sturdy materials	= 1 if the outer walls of the HH dwelling is predominantly made of bricks, concrete, wood or iron sheets = 0 otherwise
Roof of dwelling is made of sturdy materials	= 1 if the roof of the HH dwelling is predominantly made of iron sheets, tiles or concrete = 0 otherwise
Floor of dwelling is made of sturdy materials	= 1 if the floor of the HH dwelling is predominantly made of cement, wood or tiles = 0 otherwise
Dwelling has toilet	= 1 if the HH has a toilet facility = 0 otherwise
Main source of drinking water is piped water into dwelling, yard or plot	= 1 if the main source of drinking water for the HH is piped directly into the dwelling or into the yard or plot = 0 otherwise

Variables measuring quantities and currency values are winsorized, with the value of the 99th percentile replacing all observations with higher values. Agricultural outcomes are available for HHs that (1) owned and/or cultivated any land during the most recent cultivating season, and/or (2) owned any livestock in the previous year. Samples used to examine outcomes for maize are restricted to HHs that cultivated maize. [a]All measures relate to the female household head/spouse of household head

Table 10 First stage results

Dependent variable:	Household received input coupon(s)
Proportion of households in district receiving input coupons	0.834***
	(0.058)
Survey round = 2013	0.010
	(0.034)
Survey round = 2016–17	0.013
	(0.069)
Survey round = 2019–20	0.031
	(0.108)
Central Region*Survey round	-0.008
	(0.012)
Southern Region*Survey round	-0.014
	(0.012)
Household size	0.014***
	(0.004)
Dependency ratio	-0.000
	(0.000)
Household head characteristics	
Age	0.002**
	(0.001)
Sex - female	0.017
	(0.023)
Years lived in village	0.001
	(0.000)
Marital status - monogamous	-0.261***
	(0.024)
Marital status - polygamous	-0.251***
	(0.034)
Marital status - separated/ divorced	-0.319***
	(0.036)
Marital status - widowed	-0.329***
	(0.028)
Marital status - never married	-0.297***
	(0.073)
Observations	5,250
R-squared	0.403

Specification contains household fixed effects. The indicator for the 2010 survey round is the omitted round. Survey round is a linear time trend. Malawi has three regions. For region-specific linear time trends, the trend for the Northern region is the omitted category. 'Married' is the reference category for household head marital status. Standard errors presented in parentheses are clustered at the district-level.. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$

Table 11 Impacts of Malawi's Farm Input Subsidy Program (FISP) on fertilizers and crop yields (in kilograms (kg) per acre)

	(1)	(2)	(3)	(4)
Dependent variable:	Quantity of inorganic fertilizer used (in kg per acre)[a]	Quantity of inorganic fertilizer used (in kg per acre) for Maize[a]	Logged quantity of total crop yields (in kg per acre)	Logged quantity of crop yields (in kg per acre) for Maize
Household received input coupon(s)	1.433***	1.318***	1.030**	1.215**
	(0.398)	(0.401)	(0.465)	(0.534)
Observations	5,250	4,953	5,072	4,803
Number of households	1,040	1,020	1,032	1,020
Dependent variable mean for households not receiving coupons	3.180	3.271	6.538	6.072
First stage instrument F-statistic	207.75	184.17	221.40	184.60

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. All specifications control for survey wave fixed effects, region-specific linear time trends, household size, dependency ratio and household head characteristics (age, sex, marital status and years lived in the village of residence). Standard errors presented in parentheses are clustered at the district-level. *$p < 0.1$; **$p < 0.05$; ***$p < 0.01$. [a]We look at the inverse hyperbolic since transformation of these measures

Table 12 Impacts of Malawi's Farm Input Subsidy Program (FISP) on diet diversity

Dependent variable:	Food Consumption Score
Household received input coupon(s)	5.176
	(4.101)
Observations	5,250
Number of households	1,040
Dependent variable mean for households not receiving coupons	44.715
First stage instrument F-statistic	207.75

Estimation conducted using instrumental variable models with household fixed effects. Whether a household received an input coupon in a given year is instrumented for by the proportion of households in the district that received input coupons that year. Diet diversity is measured using the World Food Programme's Food Consumption Score (WFP, 2008). All specifications control for survey wave fixed effects, region-specific linear time trends, household size, dependency ratio and household head characteristics (age, sex, marital status and years lived in the village of residence). Standard errors presented in parentheses are clustered at the district-level. *$p<0.1$; **$p<0.05$; ***$p<0.01$

Declarations

Conflict of interest None.

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