Title

Subsidising improved legume seeds for increased household dietary diversity: Evidence from Malawi's Farm Input Subsidy Programme with implications for addressing malnutrition in all its forms

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Abstract

Many sub-Saharan African countries implementing agricultural input subsidies programmes (AISP) concentrate on fertilizers and staple food crops which may have little or no effect on consumption of diverse nutrient dense non-staple foods. The programme in Malawi – the Farm Input Subsidy Programme (FISP) – includes legume seeds, but little research has been undertaken to evaluate the effects of this strategy on household dietary diversity. In this study, we used two waves of integrated household panel survey data of 2013 and 2016 to examine the dietary diversity gains from inclusion of legume seed coupons in the programme. The control function approach for dealing with selection bias into a programme is used in Poisson regression of panel data. The results show that access as well as redemption of legume coupons is positively associated with diversified diets. This is especially though location fixed effects in the southern region of Malawi, higher production diversity, greater land holding sizes and the sale of maize. Further, households that had less need to satisfy hunger through the growing of maize were those likely to redeem legume coupons. The results suggest a more nuanced pathway of impact from coupon access, redemption or type of crop produced to dietary diversity than the pathway that might be expected, and have implications for how best to understand and conceptualise the tensions and synergies between addressing different aspects of malnutrition in all its forms – and suggest the importance of addressing food insecurity constraints that potentially limit the growing of nutrient-rich legume crops as well as wider increases to dietary diversity. The results also point to the importance of the income pathway and food markets in facilitating greater dietary diversity. Further consideration of these issues by policymakers and the wider agri-nutrition community will be important to advance the discussion and research of how best to design AISP and other public policy to address malnutrition in all its forms.

Highlights

- Agricultural input subsidy programmes (AISP) often focus on staple food crops.
- We examined dietary diversity (DD) effects of subsidizing legume seeds in AISP.
- Households that accessed and redeemed subsidized legume coupons had significantly higher DD.
- Households with less need to satisfy hunger by growing maize redeemed legume coupons.
- Income from the marketing of maize supports diversification of diets.
- Achievement of food security incentivizes diverse crop production important for DD.

1. Introduction

Agricultural input subsidy programmes (AISP) are among major public investments for achieving food and nutrition security in Africa (FAO et al., 2020). National governments often use AISP to address hunger and food insecurity through targeting staple crops, with Jayne et al. (2018) documenting about ten AISP in Africa providing either universal or targeted input subsides. Their continued implementation is likely explained by their role in addressing food crises and widespread hunger – situations politically difficult for governments to ignore (Jayne et al., 2018; Walls et al., 2019). However, recent emphasis in the international community in regard to malnutrition has been on the need to address micronutrient deficiencies and dietary diversity (DD), with less focus than from many national governments on hunger and food security (Harris, 2019; Poole et al., 2021). This shift in emphasis aligns with studies including from Africa showing that a dominance in people's diets of staple foods – crops that are energy dense rather than nutrient dense – does not provide adequate nutrients required for a healthy life (Ickowitz et al., 2019; Khush et al., 2012; Nuss & Tanumihardjo, 2010). Malnutrition in all its forms – both hunger and undernourishment or food insecurity, as well as nutrient deficiencies relating to a lack of (healthy) DD – is a significant issue for social and economic development (Poole et al., 2021; Walls et al., 2019). It causes an estimated 8-11 percent loss of gross domestic product in countries of Asia and Africa (IFPRI, 2015). These losses arise from poor cognition and school achievement for children, reduced work performance for adults, and related disease burdens (FAO et al.,2020). Thus, the critical need to address malnutrition in all its forms is reflected in the Sustainable Development Goals and underpinned by recent threats posed by the COVID-19 pandemic (FAO et al., 2020; Poole et al., 2021).

In Malawi, the government implemented the Farm Input Subsidy Programme (FISP) for a 15-year period between 2005 and 2020, providing fertilizer and improved seeds below market prices to smallholder farmers. The FISP was designed to improve agricultural production, and initially addressed only staple crop (maize) production, although later it also included legume seeds to diversify crop production and address soil health through nitrogen fixing (Chirwa & Dorward, 2013). Any nutritional impacts and improvements to DD were secondary to the economic and food-security objectives, and relevant here is how AISP including the FISP in Malawi often act as vehicles for maintaining political legitimacy amongst successive governments (Chinsinga, 2012). The FISP, which targeted about 1.5 million farming families annually, was the single largest public investment in the agricultural sector in Malawi, utilizing 40-70 percent of the agriculture ministry budget and close to 10 percent of the national budget (Chirwa & Dorward, 2013). Despite its probable role in abating food crises, there is criticism that the programme overshadowed alternative investments in agriculture (Dorward & Chirwa, 2011; Kelly et al., 2003; Ragasa & Mazunda, 2018; Ragasa et al., 2015). The FISP was in 2020 replaced by the Affordable Inputs Programme (AIP), which has a similar design (described later in more detail) but targets more farmers (GoM, 2021).

A considerable body of literature addresses the effects of AISP in Malawi and beyond (Hemming et al., 2018). There are, however, few studies on the links between AISP and nutritional outcomes with a recent review by Walls et al., (2018) finding a lack of attention to an important aspect of AISP impact on malnutrition – their effects on DD. Instead, studies with an interest in nutrition-related outcomes have mainly considered changes in energy/calorie availability, generally finding positive relationship. A weak positive impact of FISP on crop diversity and dietary quality has been reported by Snapp & Fisher (2015) possibly due to observed greater cultivation and land allocation to improved maize than other crops (Chibwana et al., 2012). Recently, a localized study by Matita et al. (2021) found no association between FISP coupon receipt or cultivation of legumes with DD. Likewise, Ragasa & Mazunda (2018) found inconsistent impact of the FISP on DD with significant influence when appropriate extension services were received. Some studies have found evidence of FISP influence on DD through the income pathway, with households marketing some of their maize and using realized incomes on food purchases (Sibhatu & Qaim, 2018b). However, these studies examined AISP in terms of receipt of fertilizer vouchers, rather than using evidence of accessing a specific seed coupon.

Within the framing of the 'agriculture for nutrition' agenda there is increasing concern that the intensity of staple food production reinforced by AISP may reduce the diversity of foods available. Many studies in low-income contexts show that households consuming a variety of foods have better dietary quality and improved nutrient adequacy (Arimond & Ruel, 2004; Hall et al., 2019; Steyn et al., 2006). Whilst many AISP promote staple crops – maize, rice, and wheat (Houssou et al., 2017; Mason et al., 2013; Mason et al., 2016; Pan & Christiaensen, 2012) – a few countries have expanded targeted crops to include nutrient-rich legumes, namely Zambia, Rwanda and Malawi. In Zambia, groundnuts were included as part of a crop diversification initiative (Mason et al., 2013); Rwanda targeted crops included beans (Tuyishime et al., 2017) and Malawi provided a subsidy for legumes from 2008 to 2020 as part of the FISP (Chirwa & Dorward, 2013). Other commonly subsidized food crops are sorghum, millet, potatoes, and cassava. These developments highlight the increasing recognition from policymakers, and pressure from other stakeholders, regarding the potential for production diversity to improve diets, especially in locations where markets do not function well (Zanello et al., 2019). Evidence from several regions suggests that the relationship between production diversity and DD is positive although it varies by context (Pandey et al., 2016; Sibhatu & Qaim, 2018b). This is essentially because people's choice of foods, and diets, are most proximally influenced by context-specific characteristics of local food environments such as food availability, affordability, and diversity (Herforth & Ballard, 2016; Turner et al., 2018).

In this study, we advance understanding of inclusion of nutrient-rich foods in AISP to improve DD and consequently nutrition outcomes, drawing on Malawi's FISP as a case study. To our knowledge, no previous study has investigated the influence of accessing a legume coupon in the FISP on DD. We depart from previous studies by using panel rather than cross-sectional data, which provides us the opportunity to analyze differences in DD over time, whilst accounting for endogeneity and unobserved heterogeneous effects. Additionally, this assessment accounts for household participation in crop marketing, enabling consideration of the role of income and market access in improving DD.

2. Food and Nutrition Security in Malawi

Malawi's agricultural policy has despite changes over time maintained a primary focus on maize sufficiency. Maize dominates diets in Malawi, and what has been considered a food crisis in Malawi is thus equated to maize supply below national requirements (Smale, 1995). Figure 1 shows that from 1984, cereal production in Malawi on average made up the greatest share of national crop production until 1996-99, when production of roots and tubers surpassed that of cereals. The average share of pulses, and nut production, stood at less than 5 percent of total crop production across the whole period. In terms of land allocation, increasingly more plots are used for maize cultivation. Maize dominates the types of cereals produced; for instance, in the 2015/16 farming season about 76 percent of plots (averaging 0.8 acres in size) were allocated to maize production, followed by 19 percent of plots to pigeon pea cultivation (NSO, 2017). Other crops such as groundnuts, beans, soya, and rice were reported on less than 10 percent of cultivated plots – a finding that supports sustained relatively low production of pulses and nuts.

[Figure 1]

Some explanation for these trends in crop production can be found in government policy actions. For instance, Malawi experienced delays in seed technology advancement especially for food crops because estates largely focused on tobacco production did not have enough interest in such technology (Smale, 1995) and heavy taxes on smallholder farmers between 1966 and 1979 were not reinvested (Harrigan, 2008). Investments in research and development on maize varieties was only apparent in the 1980s, and on groundnuts in 1990s, when the National Seed Company released improved varieties. However, deregulation and privatization of previously state-run companies under structural adjustment policies led to collapse of the seed industry. This resulted in an emergence of private multinational companies that concentrated more on hybrid maize seed production, leaving out other food crops partly due to maize prominence and market prospects in AISP (Chinsinga, 2011). In addition, removal of subsidies and credits extended to farmers resulted in increases in input prices which, compounded by devaluation of the Malawi Kwacha at that time, created affordability challenges in a context where poverty was already entrenched. Provision of government extension services was scaled down and other players started offering these services later in the 2000s consistent with pluralistic extension policy (Masangano & Mthinda, 2012) but to date uptake of technologies among smallholder farmers remains low (Ragasa & Niu, 2017). The role of the state in agricultural development and marketing shrank but the private sector weakly filled the gap (Chinsinga, 2012) and the legume sector remains neglected (Chinsinga & Matita, 2021).

Amidst all this, the population of Malawi increased from approximately 4.0 million in 1966 to 17.5 million in 2018, increasing food requirements. This and the situation described above, coupled with persistent challenges of low productivity, weather variability related to climate change, soil degradation and land pressures, presents a substantial threat to food and nutrition security. Indeed, Malawi has periodically experienced food crises, notably in 1992-93 and 2001-03 (Harrigan, 2008), and undernourishment affects nearly 20 percent of the population (FAO et al., 2018; GoM, 2015). Malnutrition remains a substantial challenge with high prevalence of stunting in under-5 children (37 percent in 2017, although down from 49 percent in 2000) (Figure 2). Previous studies have also reported increases in micronutrient deficiencies coupled with reduced DD among the rural poor in this context where only 25 percent of children aged 6-23 months old have minimum DD (NSO & ICF, 2017; Verduzco-Gallo et al., 2014). Furthermore, the prevalence of obesity in women has risen from 9 percent in 1992 to 21 percent in 2015-16, an increasing risk of non-communicable diseases (NSO & ICF, 2017). These problems of food inadequacy or undernourishment, micronutrient disorders and so-called over-nutrition are compounded by the increasing cost of a nutritionally adequate diet in Malawi (FAO et al., 2020).

[Figure 2]

3. The Malawi Farm Input Subsidy Programme

AISP in Malawi have taken different names, forms, and functions over time; ranging from assisting with drought recovery, alleviating hunger, addressing declining soil fertility, and improving maize productivity. As previously mentioned, the FISP was replaced by the AIP in 2020, largely due to political sensitivities related to the change of government at that time. However, with all the subsidy types, there are several common concerns, namely: distortion of private sector input delivery, increased inappropriate dependence on maize, huge cost vis-a-vis opportunity cost, and operational challenges. AISP designed to address these challenges are branded as ‘smart subsidies’ and the FISP included some of these features (Chirwa & Dorward, 2013).

The primary aim of Malawi’s FISP was to improve food production and raise farmers’ incomes. The beneficiary targeting criteria changed over time, but ranged between 900,000 and 2.2 million farming families (Nkhoma, 2018), and recently 3.8 million under the AIP (GoM, 2021). While the targeting criteria was resource-constrained farmers with land, over time there were variations in practical definition, and targeting inefficiencies were observed (Chirwa & Dorward, 2013). The largest component of the programme was inorganic fertilizers followed by improved maize seeds (Figure 3). The FISP package also included, from the 2007/08 farming season, a flexible legume coupon that allowed beneficiaries to redeem seeds for groundnuts, pigeon peas, cow peas, soybeans, and common beans. The legume seed component rose to a high of an estimated 3000MT but later declined to 1000MT in 2017/18. These figures correspond to the total amount of legumes distributed in terms of total quantity of maize of 18 percent in 2009/10; 40 percent in 2015/16 and 24 percent in 2017/18 (Chirwa & Dorward, 2013; Logistics Unit, 2016, 2017). On average, 15 and 16 percent of the households in this study accessed the legume coupon in 2013 and 2016, respectively. Of the legume coupon recipients, close to 90 percent of the households redeemed the legume coupons for improved seeds. A similar pattern was obtained with respect to redemption of maize and fertilizer coupons, supporting observations of Chirwa & Dorward (2013) that the majority of FISP recipients redeem their coupons for farm inputs. The reasons for failure to redeem legume coupons included factors such as unavailability of legume seeds at the input supplier outlet, long distances to the outlet market, and selling-on or gifting the coupons to non-household members.

[Figure 3]

The FISP underwent several reforms to improve its efficiency and outcomes (Nkhoma, 2018), including the introduction of private input suppliers in 2016/17 and increases in farmer contribution. Prior to 2015/16, beneficiary selection and coupon allocation involved local communities but from 2015/16 the Agriculture Ministry piloted a random selection of beneficiaries in a bid to target productive farmers rather than those favoured by distribution at the community level. While this much has been reported, nonetheless, the particulars about the criteria for selecting the productive farmers have not been made public (Logistics Unit, 2017). Several modifications have been made to the FISP's replacement, the AIP, namely: the use of biometric data to redeem inputs; expansion of cereal types to include a choice of maize or sorghum or rice; and the discontinuation of legumes in the programme due to fiscal space (GoM, 2021).

Since inception of the FISP, national food availability of maize from own production largely increased, ranging from 0.5 million MT to 1.2 million MT per annum, with deficits in several years attributed to weather-related events (FAO et al., 2018). Similarly, legume production continued to rise post FISP implementation with local direct demand for legumes projected to rise (Dzanja et al., 2017). Legumes play a fundamental role in farming livelihoods and are an important cash earning crop as well as food crop in Malawi. However, use of recycled or inferior seeds remains a problem to improving yields, and also worsens the presence of aflatoxin, especially in groundnuts, and stifles international exports (Derlagen & Phiri, 2012; Nyondo et al., 2018).

4. Conceptual Issues

The conceptual link between AISP such as the FISP and nutrition outcomes is that households use resources (such as improved seeds and fertilizer) provided by the agricultural interventions to maximize realized returns - income and food production (Kanter et al., 2015; Matita et al., 2021; Pandey et al., 2016). The increased production of crops supports household direct food consumption whilst income realized from crop sales can assist with food and non-food purchases. In addition, a range of factors related to farming characteristics and practices, household capabilities and assets, environmental factors, and the characteristics of institutions like food markets interact in complex ways to shape food choices, DD and nutrition and health outcomes.

The food environment (made up of food sources including food markets and own production) is the interface between agricultural production, diets, and nutrition. Characteristics of food environments include food availability, price, convenience, as well as product properties, promotional information, marketing and regulation of different food products (Herforth & Ahmed, 2015; Turner et al., 2018). Together, these different characteristics influence how people produce, acquire, and consume food within the wider food system (Turner et al., 2018). Thus, production of subsidized legumes under the FISP, *ceteris paribus*, influences the foods available (by expanding production and diversity of crops cultivated), and their price, nutritional quality, safety, and marketing, among others.

In terms of AISP impact on food choices and consumption, a household may choose to utilize the resulting produce for own consumption - this would be a typical case where production decisions align with consumption decisions (Singh et al.,1986) such that greater diversity of food crops produced results directly in more diverse food varieties available for the household's consumption (Pingali, 2015). On the other hand, a household may decide to market their harvested legumes or staple crops, in which case the influence of this production on DD would be indirect through the income pathway given that the household may use some of the income from their sales to purchase other foods. For households that source their legumes from the market or supplement own production with market purchases, the price of the commodity becomes key. Increased legume production may result in a greater market supply of different legume types, with this greater production quantity suppressing real prices. In turn, net buyers of legumes would experience savings from the reduced prices which would in many cases be channeled to other purchases, both food and non-food. But several other factors affect these relationships in a wider context shaping crop marketing and food market purchases and so may not necessarily lead to improved nutrition outcomes (Carletto et al, 2017; Zanello et al., 2019).

Furthermore, at household level the effects of including legumes in FISP on DD are also mediated by gender and intrahousehold characteristics. The FISP prioritized female-headed households in beneficiary selection. Yet, women were in fact found to be disadvantaged by the programme, due to being more likely than men to face challenges with redeeming coupons at market outlets (Chirwa & Dorward, 2013; Lunduka et al., 2013), and facing greater challenges with crop productivity (Karamba & Winters, 2015; Kilic et al., 2014). In addition, women experience more limited control over the use of crop sales income (Andersson et al., (2018). Other relevant mediating factors include food taste and preferences, non-food expenditures, food norms, and seasonality.

5. Methods

5.1 Data

This study uses two waves of panel data from the Integrated Household Panel Surveys (IHPS) collected in 2013 and 2016. These are nationally representative surveys collected by the National Statistical Office (NSO) with technical assistance from the World Bank as part of the Living Standards Measurement Studies (LSMS) - Integrated Surveys on Agriculture. The surveys include modules on agriculture, consumption, employment, safety nets, assets among others relevant to explaining the living conditions of Malawians, and data are collected every five years. In this analysis, we used an unbalanced panel sample of 2150 households (1197 households in 2013 and 953 households in 2016). The usable sample only includes households with information on variables of interest.

5.2 Empirical model

To investigate the causal influence of the inclusion of legume coupons in the FISP on household DD, we undertook multivariate regression analysis consistent with Zanello et al., (2019). The following model was specified:

$$DD_{it} = \beta_1 legm + \beta_2 mkt_{it} + \beta_3 ages_{it} + \beta_4 X_{it} + \beta_5 S_{it} + \beta_6 r_{it} + \varepsilon_{it} \quad (1)$$

Where i is individual household, t is period of survey, DD_{it} is the Dietary Diversity score at household level, and $legm_{it}$ is a vector capturing effects of including legumes in the FISP; it is defined as a dummy variable taking the value of one if a household accessed a legume coupon, or zero otherwise. mkt_{it} is a vector of market participation represented by dummy variables equal to one if a household sold any maize or any legumes, otherwise zero. $ages_{it}$ is a vector capturing the age structure of the household, reflecting the differential dietary demands by age group and gender (Harris-Fry et al., 2017). X_{it} is a vector denoting household characteristics including age, years of schooling, gender and main economic activity of the household head, wealth factors like assets and livestock ownership, and farm production diversity – computed using the same food groups as the DD score consistent with other studies (Sibhatu & Qaim, 2018). We also included land holding sizes to reflect the productive capacity of farmers since farmers with more land are likely to be more productive than farmers with small pieces of land (Asfaw et al., 2017). S_{it} is a vector of seasonality defined as the period when consumption data were collected, either during marketing, harvesting, pre-planting or the lean period of the agricultural season. r_{it} is a vector of location-specific effects capturing regional dummies for the south, center, and north. In an alternative specification we used the rural-urban divide to reflect economic differences in the location of residence. ε_{it} is the idiosyncratic error term.

Our outcome variable, the DD score, is defined as a count of the number of food groups consumed by a household over the past 7 days of survey as per standard guidance (FAO, 2011).

DD score measures are widely used and applied in different contexts as a proxy measure for DD and nutritional outcomes (Arimond & Ruel, 2004; Marshall et al., 2014; Ruel, 2003), or more specifically, household socioeconomic ability to access a variety of foods. FAO (2011) suggest that a more robust approach is to use a 24-hour recall period, but this was not available in the IHPS dataset. Nonetheless, Turner et al., (2018) argues that a 24-hour recall period does not accurately measure diets in contexts with varied diets and where seasonality of consumption exists as in Malawi, and according to Koppmair et al., (2016) the bias introduced by use of seven-day recall does not significantly affect DD scores. This study uses 12 food groups consistent with Swindale et al., (2006): cereals, roots and tubers, vegetables, fruits, meat/poultry/offal, eggs, fish and seafood, pulses/legumes/nuts, milk and milk products, oils/fats, sugar/honey, and spices/condiments/beverages. The commonly used DD score, while validated as a proxy for DD, is limited in some respects. For instance, features of the 'nutrition transition' associated with consumption of highly processed foods are obscured (Walls et al., 2018) as are the sizes and portions of food items consumed (Arimond & Ruel, 2004). Furthermore, the household DD score provides little information about intrahousehold inequitable allocation of food though often individual DD scores for women are used to capture such dynamics (FAO, 2011). Notwithstanding the limitations of DD scores, they are widely used in the nutrition and food systems literature.

5.3 Estimation strategy

The selection of FISP recipients was non-random therefore prone to selection bias. To address any endogeneity problems, the control function (CF) approach was employed in line with previous studies (Sibande et al., 2017; Wossen et al., 2017). The CF function was implemented in two steps:

(i) Factors affecting legume coupon access were determined using a Probit model. Several variables were used as independent variables in the model consistent with literature on participation in subsidy programs (Chirwa & Dorward, 2013; Lunduka et al., 2013; Mason & Ricker-Gilbert, 2013; Sibande et al., 2017). Further, the CF approach requires inclusion of instrumental variables (IV) in the first stage. These are variables that affect access to legume coupons but only do so indirectly for DD. Here, consistent with other studies (Fisher & Kandiwa, 2014; Ragasa et al., 2019; Ragasa & Mazunda, 2018; Sibande et al., 2017), we used a binary variable equal to one if a member of parliament had visited or resided in the constituency, and otherwise zero. The choice of this variable reflects the political and social capital that may affect access to FISP coupons. For example, a member of parliament frequently visiting an area or residing in proximity may assist with monitoring the availability of improved legume seeds in surrounding market outlets as well as attending district meetings on the programme an important contribution that could check on programme inputs delivery as well as participation. But their presence or visits in the constituency would do little to influence the variety of foods consumed at household level.

(ii) Predicted residuals obtained from stage one entered the second stage model of the determinants of DD. Poisson regression using panel data was employed since the dependent variable, DD is a count and non-negative variable that takes few discrete values (Woodridge, 2010) in line with previous studies (Matita et al., 2021; Sibhatu & Qaim, 2018b; Smale et al., 2020). A significant coefficient for the predicted residuals implies their inclusion corrects for the bias in β_1.

In addition, we also assess the mechanisms for increased household DD from legume seed coupon access by investigating heterogeneous effects. Several interaction variables were included to this effect. All estimations were bootstrapped with 50 replications to improve robustness. The data were analyzed using STATA Version 14.

6 Results

6.1 Descriptive statistics

Table 1 presents a description of the study sample. Irrespective of the subsidy coupon received, significantly more households participated in the FISP in 2013 (42.0 percent) than in 2016 (37.3 percent). The proportion accessing fertilizer was significantly higher in 2016 than 2013 with no evident differences in proportion of households accessing the seed coupons. DD was significantly higher in 2013 with an average of 8.9 food groups consumed compared with 7.6 in 2016. These figures are rather higher than the 4 food groups reported by Matita et al., (2021) and Koppmair et al., (2016) but consistent with another national study (Jones et al., 2014). About 61.2 percent reported adequate food consumption in the month prior to the survey in 2013 compared to the significantly lower proportion reporting the same in 2016 (42.4 percent). Production diversity significantly declined across the two time points, but the panel sample average was 3.0 food groups.

[Table 1]

Table 2 shows the proportion of households reporting consumption of food groups by status of legume-coupon access. Significant differences exist in the consumption of three food groups. Households that accessed the legume coupons had significantly higher consumption of white tubers and roots and oils and fats than those that did not access legume coupons, while households that did not access legume coupons had significantly higher consumption of the food group milk and milk products. The other food groups show no statistically significant differences in reported consumption.

[Table 2]

6.2 Regression results

6.2.1 Determinants of redeeming a legume coupon.

Table 3 presents determinants of legume-coupon access in the FISP from Probit estimation. There were no predictors in the model that were highly correlated based on Variance Inflation Factors reported in Table A1. Overall, the model is significant judging by the significant Wald Chi-square statistics (at 1 percent level) implying rejection of the hypothesis that all parameters are equal to zero. One of the IVs used, member of parliament resides in constituency, has a positive and significant influence on access to legume coupons ($p<0.01$). This implies that households living in communities where a member of parliament also resides are 6.0 percent more likely to access legume coupons than those where such political office bearers are not resident, a finding consistent with other literature (Fisher & Kandiwa, 2014; Ragasa & Mazunda, 2018; Sibande et al., 2017). The results further show households reporting adequate food consumption in the past month of the survey were 3.1 percent more likely to access legume coupons relative to the base category. Residence in the southern region increases the likelihood of accessing legume coupons relative to the northern region. Similar results were obtained from analyzing redemption of legume coupons relative to households that either accessed a legume coupon but never redeemed it for inputs or a household that did not receive a legume coupon (Table A2).

[Table 3]

6.2.2 Effect of accessing subsidized legume coupons on household dietary diversity

Table 4 presents results of the factors affecting DD obtained using Poisson regression of panel data. The specification in model I accounts for regional variations (reflecting agroecological & cultural differences in Malawi) whilst model II considers the rural-urban divide (reflecting economic differences) that may influence DD. This analysis assessed the assumption of Poisson models that conditional mean and conditional variance are equal and found that there was no overdispersion[1]. Overall, the obtained Wald Chi-squared statistics showed that the hypothesis that all the parameter estimates are equal to zero be rejected ($p<0.01$). The generalized residual variable was also significant implying the model estimated corrects for any endogeneity. However, no methods exist for testing weak instruments in nonlinear models adopted here, an observation also made in other studies (Sibande et al., 2017), but the CF method is considered more robust compared to IV for nonlinear estimations involving endogenous variables (Imbens & Woodridge, 2007) as cited in Ragasa & Mazunda (2018).

We find a positive and significant relationship ($p<0.01$) between access to subsidized legume coupons and DD. Households that accessed legume coupons had a 1.6- or 1.3-times higher DD than households that did not receive any legume seed coupons in models I and II, respectively. This implies that households that redeemed legume coupons are expected to have consumed at least one more food group than the base category. These results in Table 4 are consistent with the results obtained in Table A3 with higher DD score for the households that redeemed the legume coupon relative to those that either accessed a legume coupon but never redeemed it or did not receive a legume coupon.

[Table 4]

[1] The five percent critical value for a chi-squared was higher than the obtained deviance and Pearson chi-squared statistic.

The results further suggest that the importance of the maize crop for DD is through the sale of maize. Households that sold maize had a significantly higher DD score than those that did not sell any maize. Specifically, households that sold maize consumed one more food group than households that did not sell maize (Table 4). Selling of legume crops is only significant when the rural-urban differences in location of residence are considered (model II). Further, diversity in crop production was associated with significantly higher DD.

The positive effects of wealth (as measured by TLU, the asset index and land) on DD supports evidence regarding the influence of income on DD, a hypothesis widely supported in literature (Jones, 2016; Snapp & Fisher, 2015). Households whose consumption data were collected during the harvest period experienced significantly higher DD relative to the lean period, consistent with the literature (Matita et al., 2021; Zanello et al., 2019). The presence of females (aged 15-55 years) in the household was also associated with higher DD, supporting findings from other studies of the role of women in safeguarding household consumption (Amugsi et al., 2016; Nisbett et al., 2017; Sraboni et al., 2014).

We find the regions of the south and center of Malawi were associated with negative DD relative to the north (Table 4). In model II, the differentiation by rural-urban status shows that those households in urban areas had higher DD relative to those in rural areas. In addition, heterogeneous effects assessment in Table 5 demonstrates that residence in the southern region strongly facilitates effectiveness of legume coupons in influencing DD ($p<0.01$). Households that accessed legume coupons and resided in the southern region had higher DD (by one food group) than those in the northern region and who did not receive legume coupons. This relationship was found to be weakly positive in the central region ($p<0.05$). Further, in Table 5, the association between accessing legume coupon and DD was strengthened with higher production diversity, greater land holding sizes and the sale of maize ($p<0.01$). But households that accessed legume coupons and sold legume crops experienced significantly lower DD. Similar results are obtained when actual redemption of legume coupons is considered in the estimation as presented in Table A4, but the heterogeneous effects of the central region on DD are no longer significant.

[Table 5]

7 Discussion and conclusions

Dietary diversification remains a challenge in countries with low food security[2] and widespread micronutrient deficiencies and undernourishment (FAO et al., 2020). There has been considerable criticism from the global nutrition community of contexts where ‘agriculture for nutrition’ strategies are perceived as biased towards reducing hunger and undernourishment with far less emphasis on achieving diverse diets, through for example production diversity and especially in settings where markets do not function well. Furthermore, there has been considerable support from international organizations and agri-nutrition scholars internationally for the inclusion of legumes and other non-staple crops in AISP, to support greater diversification of diets.

In this study, we found strong evidence to suggest that the type of subsidized seed coupon accessed matters for DD. However, we also found evidence for a more nuanced pathway of impact from coupon access, redemption or type of crop produced to DD than the pathway that might be expected – of greater legume production directly resulting in greater DD. Our findings also have implications for how public health nutrition stakeholders conceptualize the tensions and synergies between and advocate for how best to address malnutrition in all its forms (Harris, 2019; Poole et al., 2021; Walls et al., 2019), and specifically for hunger and undernourishment as well as nutrient deficiencies and DD.

We found that access and redemption of legume coupons was associated with greater DD. This finding appears to support the conclusion of Smale et al., (2020) that consumption of an adequate diet could be enhanced with inclusion of nutrient-rich foods as in Mali’s AISP, but it differs from the localized study in Malawi of Matita et al., (2021) which found no effects of cultivating legumes or participation in the FISP on DD. In any case none of these studies assessed the impact of specific crop coupon redemption in the AISP on DD. The results should also be interpreted in the context of studies finding inconsistent effects of the FISP on child anthropometry and weak linkages to

[2] Defined as low quality, variety, quantity and frequency of food consumption (NSO, 2017)

DD (Harou, 2018; Walls et al., 2018) but positive effects of production diversity on DD (Sibhatu & Qaim, 2018).

Across regions, we found the effect of accessing subsidized legume coupons on DD was context-specific with strong and significant positive influence among residents in the southern region of Malawi. This southern region is an area with high population densities; characterized by mixed farming systems and low land holding sizes which in particular drives households to intercrop maize with leguminous plants as a strategy to address food insecurity – thereby resulting in more diverse crop production and more diverse diets as described by several scholars (Asfaw et al., 2012; Harou, 2018; Mhango et al., 2012; Simtowe et al., 2016). It follows that, in the southern region, when farmers are incentivized by legume coupons, they are likely to grow more legumes. In the central region however, despite such incentives farmers appear to have diversified their legume production to a lesser extent, with maize and tobacco continuing to dominate cultivation.

Nonetheless, the finding that the general *sale* of maize – but not consumption of maize – is associated with higher DD emphasizes the role of crop income in facilitating access to a variety of foods. This finding is particularly important in the context of other literature which failed to find direct links between DD and maize consumption (Harou, 2018) or maize cultivation (Snapp & Fisher, 2015). Together, these findings suggest that growing maize, a carbohydrate – supported by coupons for maize seed – may not allow households to diversify their diets. However, whilst this may be the case, it appears from our findings that those households that sell maize, perhaps after growing enough for their own consumption, are those able to use this income to diversify their diets. However the paradox is that most households that grow maize are not selling it as they do not have adequate surplus – a finding also corroborated by Sibande et al., (2017) who observed low maize commercialization in Malawi despite FISP implementation.

Furthermore, in this study having adequate food, which is synonymous for these Malawian study participants with having enough maize, emerged as a significant predictor of the decision of whether to access or redeem legume coupons. Thus, taken together, these findings suggest that those households that have less hunger and less immediate need to satisfy hunger through the growing of maize are the households that can choose to redeem legume coupons and grow legumes. So, the growing of legumes, rather than being the causative factor in more diversified diets, might instead be a marker of a household's level of food security, which itself influences household choices about diversified crop production, and through this more indirect pathway shapes DD. Supporting this interpretation was our finding that those households that redeemed legume coupons had larger land holding sizes and sold more maize relative to their counterparts. Furthermore, the positive effects of household wealth on DD found here enhances this understanding that better-off households are likely to be less food insecure and therefore grow food crops other than maize, such as legumes.

Several implications arise from these findings. These relate to both the design of AISP, as well as wider thinking in the agri-nutrition community regarding the tensions and compatibilities of addressing different forms of malnutrition.

First, whilst initially the association between the access to legume coupons and greater DD through the crop diversity pathway appears to suggest particular opportunities to leverage AISP for better nutrition, in fact the situation appears to be more complex. Rather than the objectives of producing more food and addressing hunger and food insecurity being at odds with the 'agriculture for nutrition' agenda, our findings suggest that the achievement of food security may be paramount to being able to achieve nutritional objectives regarding increased DD. The cultivation of maize allows households to achieve energy food requirements, and whilst this fails to enhance diet diversity, our results suggest that those households that did achieve a surplus of maize were then able to make the choice to diversify their production into legumes – and particularly so if supported by the legume subsidies.

Second, an implication of our findings is the possibility of false dichotomies being drawn between focuses on 'nutrition' or 'hunger' – and that rather, they are complementary and synergistic. Food security may perhaps be primary, but once attained it appears to create synergies among smallholder farmers with addressing other forms of malnutrition. This finding is in fact broadly consistent with previous literature alluding to their compatibility (Poole et al., 2021; Walls et al., 2019).

Third, our findings highlight the critical role of household incomes and food markets in shaping nutritional outcomes. AISP pathways of impact to improved nutritional outcomes require access to functional output markets to improve incomes, some of which can then support the purchase of diverse foods (Ickowitz et al., 2019; Matita et al., 2021). Addressing food insecurity and poverty could ease smallholder farmer constraints to greater legume production and greater engagement with output markets and support the achievement of more diversified diets.

Our study has several limitations. These include those mentioned earlier regarding the measurement of DD. Furthermore, although this study utilizes panel data, the point reference to redemption of legume coupons fails to account for potential long-term effects of the FISP with more enduring benefits, as observed by Ricker-Gilbert & Jayne (2017). Additionally, due to the absence of information about the criteria used to select productive farmers for participation in the FISP in 2015/16, we are not able to fully account for the differences in beneficiary selection for the two panel years. Instead, we note the general potential for selection bias in the analyses of these relationships. Despite, these shortcomings, this research provides important insights with potential for further development into the role of non-staple AISP in shaping DD, food insecurity and nutrition – an area as far as we are aware not previously investigated.

In summary, there appears to be a role for providing AISP or other transfers to allow households to better access quality legume seeds in AISPs, especially in locations like southern Malawi where the cultural context is already more favourable to growing legumes. However, the general focus of subsidy programmes on staple crops such as maize may not be as misguided as is sometimes characterized, given the role of maize in addressing hunger and undernourishment – something that this study suggests may be as important if not more important to the achievement of DD as the production of diverse crops themselves. Furthermore, the importance of household income in these pathways suggests that AISP may not be the only or even the best way to address malnutrition in Malawi, with cash transfers and other social support systems being critical, alongside the role of well-functioning markets. Further consideration of these issues by policymakers and the wider agri-nutrition community will be important to advance discussion and research of how best to design AISP and other public policy to address malnutrition in all its forms.

Declaration of interest: none

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Table 1: Descriptive statistics (mean values) of the study sample

Variable	IHPS 2 (2013)	IHPS 3 (2016)	All households	SD
HH dietary diversity	8.865	7.609***	8.306	2.08
Received any subsidy coupon (1/0)	0.420	0.373**	0.399	0.49
Accessed legume coupon (1/0)	0.149	0.158	0.153	0.36
Redeemed legume coupon (1/0)	0.921	0.907	0.915	0.28
Accessed fertilizer coupon (1/0)	0.419	0.462**	0.438	0.50
Accessed maize coupon (1/0)	0.227	0.250	0.237	0.43
Age of HH head (years)	41	44***	43	14
Adult equivalent	4.404	4.681***	4.527	2.01
Male headed HH (1/0)	0.799	0.750**	0.777	0.42
HH head years of schooling	6.976	6.092***	6.584	3.89
Head in wage employment (1/0)	0.177	0.103***	0.144	0.35
Head in agriculture employment (1/0)	0.659	0.663	0.661	0.47
Head in business enterprise (1/0)	0.126	0.116	0.122	0.33
Head in '*ganyu*' employment (1/0)	0.035	0.115***	0.071	0.26
Asset index	0.798	0.640	0.728	4.07
Adequate food in past month (1/0)	0.612	0.424***	0.528	0.499
Total livestock units (TLU) (1/0)	0.219	0.242	0.229	0.48
Farm production diversity	3.241	2.678***	2.991	1.37
Obtained credit (1/0)	0.258	0.274	0.265	0.44
Land holding (ha)	0.657	0.695	0.674	0.603
MP visited in past month (1/0)	0.125	0.073***	0.102	0.303
MP resides in the community (1/0)	0.085	0.207***	0.139	0.346
Southern region (1/0)	0.466	0.499	0.466	0.499
Central region (1/0)	0.4369	0.497	0.44	0.497
Number of observations	1197	953	2150	

Notes: Table 1 presents mean values and standard deviation (SD) of the study sample. The statistics are presented separately for the two study years and for all households in the panel sample. The test of mean differences for the two years of study is included. (1/0) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 2: Food consumption groups and legume coupon access (%)

Food consumption group	Households reporting food consumption (%)	
	HH accessed legume coupon	HH did not access legume coupon
Cereals	100.0	99.8
White tubers and roots	76.1	70.6**
Vegetables	100.0	99.7
Fruits	65.4	63.8
Meat	46.2	49.6
Eggs	41.2	37.0
Fish and seafood	42.5	39.7
Legumes, nuts, and seeds	92.7	91.0
Milk and milk products	16.6	21.7**
Oil and fats	84.7	80.1*
Sweets	78.7	75.6
Spices, condiments, and beverages	100.0	99.8

Notes: Table 2 shows proportion of households reporting food groups with consumption by legume coupon access status. The test of mean differences by legume coupon access status is included. The proportions were computed for all households in the panel sample. HH= household. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3:Determinants of access to subsidized legume coupon

Dependent variable: Legume coupon access (regardless of how obtained/used)	Average Marginal Effects	Standard Error
Age of HH head (years)	0.011***	0.003
Age of HH head squared	0.000***	0.000
Adult equivalent	0.001	0.004
Male headed HH (1/0)	-0.005	0.017
HH head years of schooling	-0.002	0.003
Head in wage employment (1/0)	-0.067*	0.037
Head in agriculture employment (1/0)	-0.011	0.028
Head in business enterprise (1/0)	-0.003	0.036
Asset index	-0.138	1.514
Asset index squared	0.006	0.067
Adequate food in past month (1/0)	0.031**	0.014
Total livestock units (TLU) (1/0)	0.004	0.016
Obtained credit (1/0)	-0.014	0.018
Land holding (ha)	0.114***	0.032
Land holding squared	-0.034***	0.012
MP visited in past month (1/0)	0.048**	0.026
MP reside in community (1/0)	0.060***	0.025
Head always lived-in village (1/0)	0.002	0.018
Southern region (1/0)	0.175***	0.028
Central region (1/0)	-0.016	0.028
Wald Chi-squared	181.706***	
Number of observations	2150	

Notes: Table 3 shows unbalanced panel Probit estimates of the determinants of accessing subsidized legume coupons obtained using Generalized Linear Models with binomial distribution. (1/0) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category. MP=Member of Parliament. Standard errors in parentheses

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Relationship between accessing legume coupon and dietary diversity

Dependent variable: Household DD	CF approach (I)		CF approach (II)	
	IRR	SE	IRR	SE
Accessed legume coupon (1/0)	1.648***	(0.165)	1.256***	(0.062)
Sold any maize (1/0)	1.041***	(0.012)	1.042***	(0.013)
Sold any legumes (1/0)	1.014	(0.011)	1.023*	(0.012)
Production diversity	1.027***	(0.004)	1.031***	(0.004)
Asset Index (1/0)	1.006***	(0.001)	1.003***	(0.001)
Land holding (ha)	0.900***	(0.024)	0.979	(0.022)
Land holding squared	1.037***	(0.009)	1.011	(0.008)
Total livestock units	1.029***	(0.010)	1.040***	(0.009)
Age of HH head (years)	0.998	(0.002)	0.999	(0.003)
Age of HH head squared	1.000	(0.000)	1.000	(0.000)
Years of schooling for head	1.014***	(0.002)	1.012***	(0.001)
Head is married (1/0)	1.012	(0.022)	1.008	(0.020)
Male headed household (1/0)	1.012	(0.022)	1.007	(0.020)
HH with male adults only (1/0)	1.039	(0.035)	1.038	(0.032)
HH male and female adults (1/0)	1.006	(0.022)	1.010	(0.018)
No. male under5 children	0.986*	(0.008)	0.986	(0.009)
No. male children 6-14 yrs	0.989	(0.007)	0.990	(0.006)
No. male adults 15-55 yrs	1.003	(0.006)	1.001	(0.005)
No. male adults >55 yrs	0.987	(0.015)	0.984	(0.017)
No. female under 5 children	0.984**	(0.007)	0.984*	(0.008)
No. female children 6-14 yrs	0.987**	(0.005)	0.987**	(0.006)
No. female adults 15-55 yrs	1.018**	(0.008)	1.019***	(0.007)
No. female adults >55 yrs	1.003	(0.016)	1.003	(0.015)
Head in wage employment (1/0)	1.204***	(0.038)	1.167***	(0.027)
Head in agriculture (1/0)	1.070**	(0.031)	1.082***	(0.023)
Head in business enterprise (1/0)	1.166***	(0.035)	1.157***	(0.026)
Harvesting season (1/0)	1.062***	(0.015)	1.064***	(0.016)
Marketing season (1/0)	1.027**	(0.014)	1.032**	(0.016)
Southern region (1/0)	0.946***	(0.018)	-	-
Central region (1/0)	0.888***	(0.023)	-	-
Urban residence (1/0)	-	-	1.170***	(0.017)
Generalized Residual	0.615***	(0.064)	0.809***	(0.040)
Wald Chi-squared	263.838***		293.754***	

Notes: Table 4 presents exponentiated coefficients also called Incidence Rate Ratio (IRR) based on Poisson regression of unbalanced panel data of the relationship between access to subsidized legume coupons and DD. The Incidence Rate Ratio (IRR) is the ratio of the expressed category to the base category or exponential of intercept plus coefficient times the value of *X*. HH= Household. DD= Dietary Diversity. CF = Control Function approach. The coefficients were obtained from a Generalized Linear Model estimation with a Poisson distribution. (1/0) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 5: Heterogeneous effects of access to subsidized legume coupon

Dependent variable: HDD	CF approach	
	IRR	SE
Other control variables	yes	
Accessed legume coupon &		
Head in agriculture (1/0)	1.055	(0.069)
Head in wage employment (1/0)	0.991	(0.073)
Head does business (1/0)	1.011	(0.076)
Central region (1/0)	1.135*	(0.084)
Southern region (1/0)	1.195***	(0.075)
Production diversity	1.025***	(0.008)
Asset index	1.003	(0.004)
Total livestock units	1.018	(0.026)
Sold maize (1/0)	1.100**	(0.043)
Sold legumes (1/0)	0.950*	(0.028)
Land holding (ha)	1.048**	(0.024)
Wald Chi-squared	2469.355***	

Notes: Table 5 shows heterogeneous effects of accessing subsidized legume coupon on dietary diversity obtained using the control function approach. Only interaction terms are presented in this table, but several control variables were included in the estimation. (1/0) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

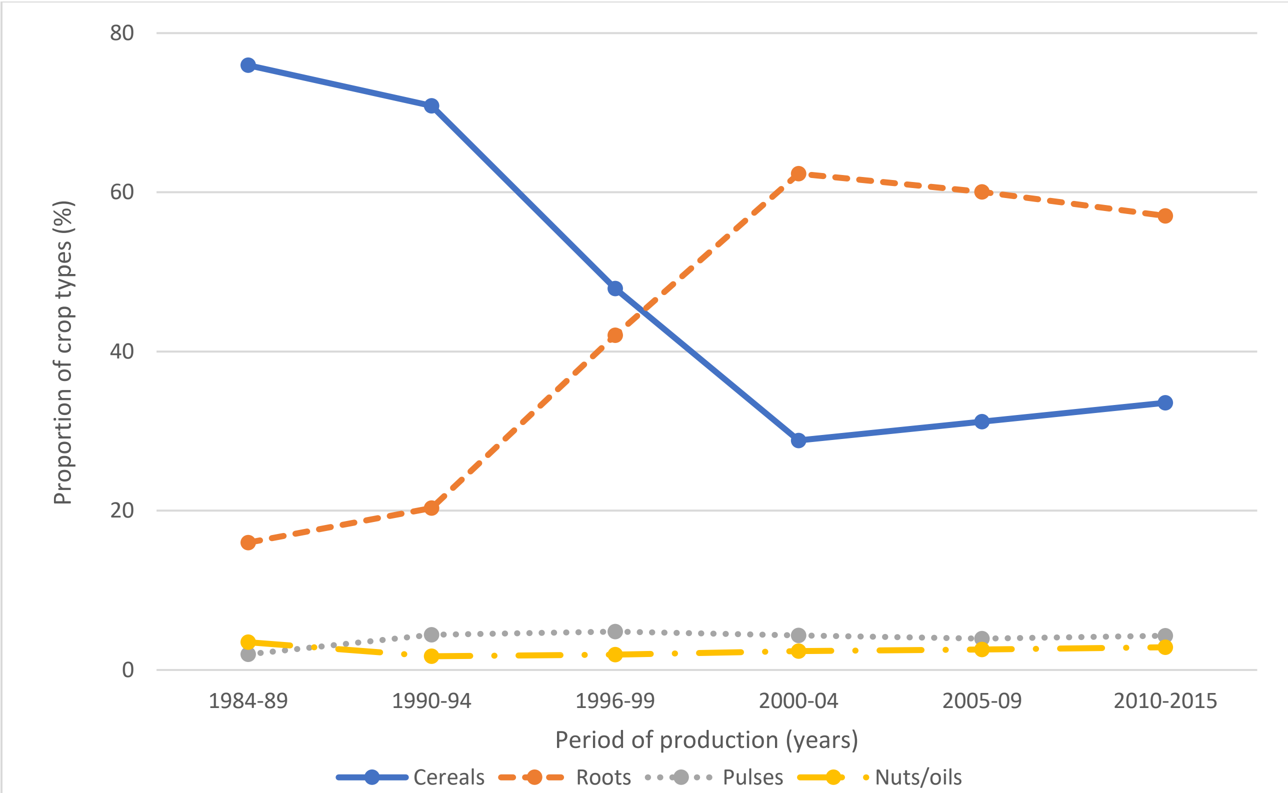

Figure 1: Trends in average share of crop types in Malawi

Source of data: FAOSTAT (2015)

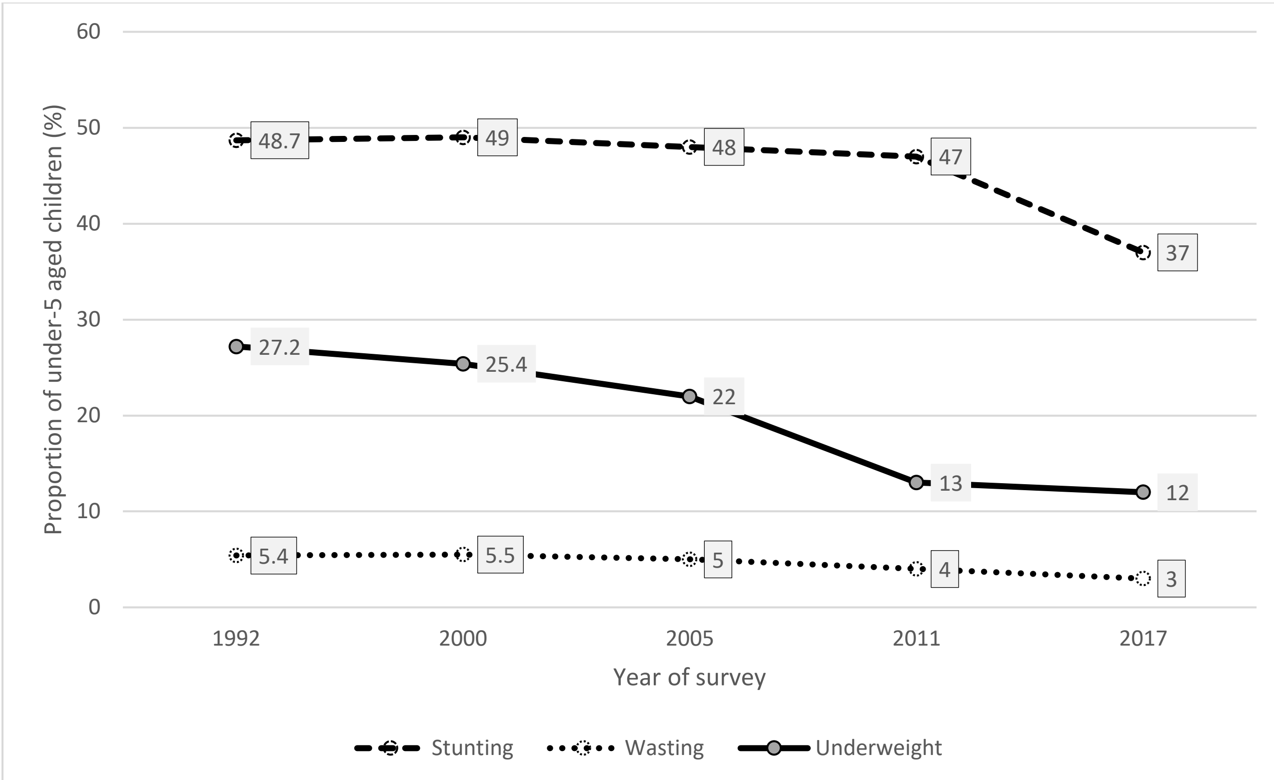

Figure 2: Trends in nutrition indicators

Source: Updated from Chirwa & Ngalawa (2008) based on various Demographic and Health Surveys and Multiple Indicators Survey by the National Statistical Office (NSO, 2011; NSO & ICF, 2017).

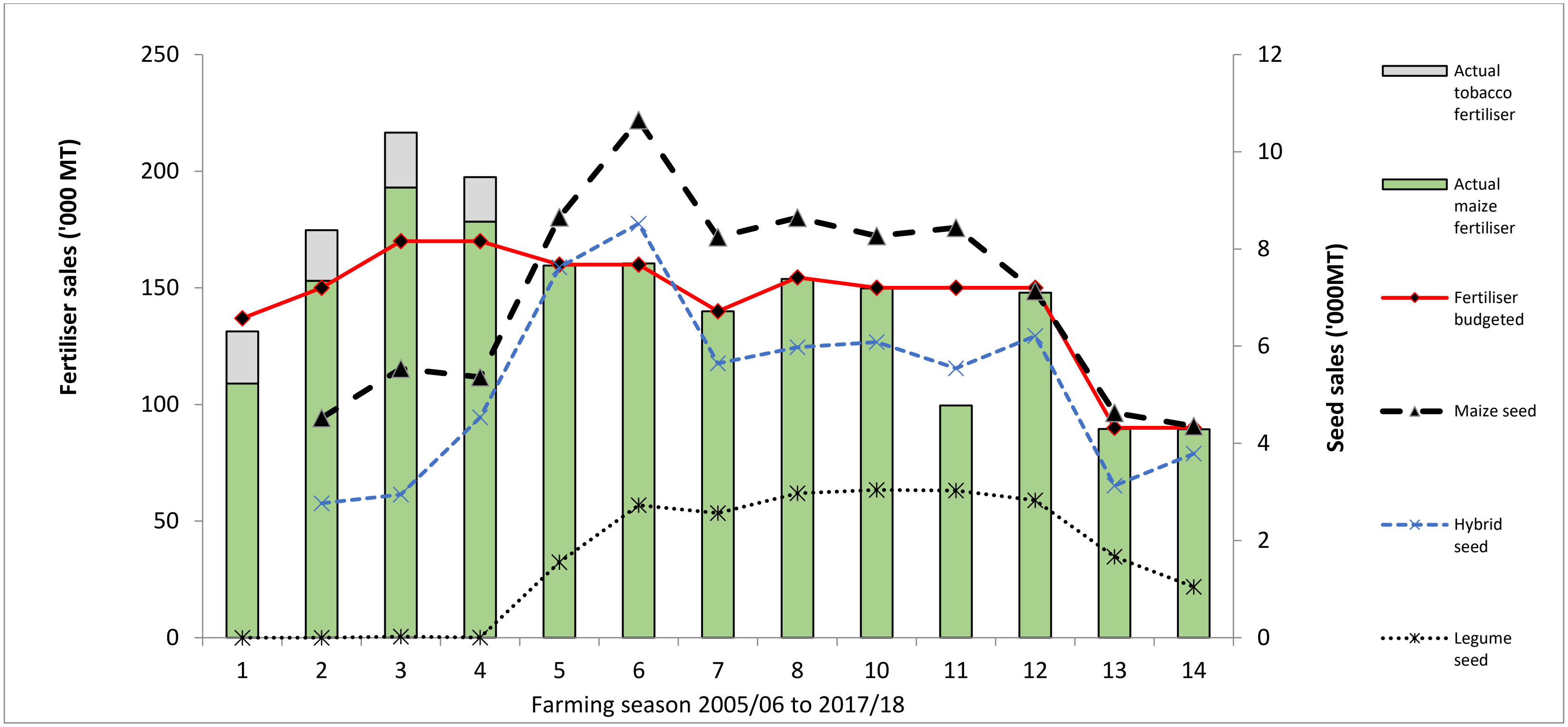

Figure 3: Trends in sales of subsidized fertilizer and seed by year

Notes: Figure shows trends in sales of subsidized fertilizer and seed volumes over the years. The numbers 1 to 14 on the x-axis refers to the farming seasons for the period from 2005/06 to 2017/18. Updated from Dorward & Chirwa (2014) based on calculations from Logistics Unit Reports on Implementation of Agricultural Input Subsidy Programme (Logistics Unit, 2016, 2017). MT= metric tons.

Subsidising improved legume seeds for improve household dietary diversity

Table A1: Variance Inflation Factor (VIF) for variables used in models

Variable	VIF
Head in agriculture (1/0)	3.51
Southern region (1/0)	3.47
Central region (1/0)	3.37
Head in wage employment (1/0)	2.85
HH male and female adults (1/0)	2.54
Male headed household (1/0)	2.49
Head in business enterprise (1/0)	2.41
Head is married (1/0)	2.4
Age of household head	2.37
Harvesting season (1/0)	1.96
Marketing season (1/0)	1.96
No. male adults >55 yrs	1.88
HH with male adults only (1/0)	1.82
No. male adults 15-55 yrs	1.69
No. female adults >55 yrs	1.59
Sold any legumes (1/0)	1.45
Years of schooling for head	1.38
No. female adults 15-55 yrs	1.37
Sold any maize (1/0)	1.28
Asset Index	1.18
No. female under 5 children	1.17
No. male under5 children	1.16
Production diversity	1.16
Accessed legume coupon (1/0)	1.11
Total livestock units	1.1
No. female children 6-14 yrs	1.1
No. male children 6-14 yrs	1.09
Mean VIF	1.88

Table A2: Determinants of redeeming a legume coupon

Dependent variable: Legume coupon redemption	Average Marginal Effects	Standard Error
Age of HH head (years)	0.010***	0.003
Age of HH head squared	0.000***	0.000
Adult equivalent	0.000	0.005
Male headed HH (1/0)	-0.012	0.017
HH head years of schooling	-0.002	0.002
Head in wage employment (1/0)	-0.060	0.031
Head in agriculture employment (1/0)	-0.005	0.028
Head in business enterprise (1/0)	0.009	0.034
Asset index	-0.127	1.528
Asset index squared	0.006	0.067
Adequate food in past month (1/0)	0.036**	0.015
Total livestock units (TLU) (1/0)	0.011	0.015
Obtained credit (1/0)	-0.005	0.015
Land holding (ha)	0.103***	0.036
Land holding squared	-0.031**	0.014
MP visited in past month (1/0)	0.041*	0.021
MP reside in community (1/0)	0.049**	0.023
Head always lived-in village (1/0)	-0.001	0.014
Southern region (1/0)	0.174***	0.027
Central region (1/0)	-0.004	0.032
Wald Chi-squared	170.317***	
Number of observations	2150	

Notes: Table A2 shows unbalanced panel Probit estimates of the determinants of legume coupon redemption obtained using Generalized Linear Models with binomial distribution. The based category for the dependent variable is a household that either accessed a legume coupon but never redeemed it for inputs or HH that did not receive a legume coupon. (1/0) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category. MP=Member of Parliament. HH=household. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A3: Relationship between redeeming a legume coupon and dietary diversity

Dependent variable: Household DD	CF approach (I)		CF approach (II)	
	IRR	SE	IRR	SE
Redeemed legume coupon (1/0)	2.029***	(0.245)	1.308***	(0.070)
Sold any maize (1/0)	1.040***	(0.013)	1.042***	(0.014)
Sold any legumes	1.014	(0.012)	1.024**	(0.009)
Production diversity	1.027***	(0.004)	1.031***	(0.004)
Asset Index (1/0)	1.006***	(0.001)	0.978	(0.022)
Land holding (ha)	0.887***	(0.023)	1.012	(0.008)
Land holding squared	1.041***	(0.009)	1.003***	(0.001)
Total livestock units	1.023**	(0.010)	1.038***	(0.008)
Age of HH head (years)	0.996	(0.003)	0.999	(0.003)
Age of HH head squared	1.000	(0.000)	1.000	(0.000)
Years of schooling for head	1.014***	(0.001)	1.012***	(0.001)
Head is married (1/0)	1.012	(0.025)	1.007	(0.022)
Male headed HH (1/0)	1.016	(0.024)	1.009	(0.020)
HH with male adults only (1/0)	1.040	(0.028)	1.039	(0.030)
HH male and female adults (1/0)	1.006	(0.020)	1.010	(0.018)
No. male under 5 children	0.986*	(0.008)	0.986*	(0.008)
No. male children 6-14 yrs	0.990*	(0.005)	0.991	(0.007)
No. male adults 15-55 yrs	1.004	(0.006)	1.002	(0.005)
No. male adults >55 yrs	0.988	(0.017)	0.984	(0.015)
No. female under 5 children	0.985**	(0.007)	0.984**	(0.007)
No. female children 6-14 yrs	0.988*	(0.007)	0.987**	(0.006)
No. female adults 15-55 yrs	1.018***	(0.007)	1.020***	(0.007)
No. female adults >55 yrs	1.004	(0.016)	1.003	(0.013)
Head in wage employment (1/0)	1.212***	(0.031)	1.167***	(0.025)
Head in agriculture (1/0)	1.068***	(0.024)	1.081***	(0.022)
Head in business enterprise (1/0)	1.155***	(0.028)	1.152***	(0.027)
Harvesting season (1/0)	1.061***	(0.016)	1.064***	(0.017)
Marketing season (1/0)	1.026*	(0.016)	1.032**	(0.015)
Southern region (1/0)	0.943***	(0.020)	-	-
Central region (1/0)	0.858***	(0.024)	-	-
Urban residence (1/0)	-	-	1.170***	(0.015)
Generalized Residual	0.502***	(0.061)	0.780***	(0.043)
Wald Chi-squared	270.673***		296.031***	

Notes: Table A3 presents exponentiated coefficients also called Incidence Rate Ratio (IRR) of unbalanced panel Poisson regression of the relationship between redemption of legume coupon and DD. The Incidence Rate Ratio (IRR) is the ratio of the expressed category to the base category or exponential of intercept plus coefficient times the value of *X*. HH= Household. DD= Dietary Diversity. CF = Control Function approach. The coefficients were obtained from a Generalized Linear Model estimation with a Poisson distribution. (1/0) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table A4: Heterogeneous effects of redeeming a legume coupon

Dependent variable: HDD	CF approach	
	IRR	SE
Other control variables	yes	
Redeemed legume coupon &		
Head in agriculture (1/0)	1.069	(0.066)
Head in wage employment (1/0)	0.985	(0.074)
Head does business (1/0)	0.999	(0.072)
Central region (1/0)	1.143	(0.098)
Southern region (1/0)	1.229**	(0.104)
Production diversity	1.024**	(0.010)
Asset index	1.003	(0.004)
Total livestock units	1.010	(0.024)
Sold maize (1/0)	1.112***	(0.041)
Sold legumes (1/0)	0.943*	(0.032)
Land holding (ha)	1.058**	(0.028)
Wald Chi-squared	8385.739***	

Notes: Table A4 shows heterogeneous effects of redeeming a legume coupon on dietary diversity obtained using the control function approach. Only interaction terms are presented in this table, but several control variables were included in the estimation. (1/0) indicates dichotomous variables for the stated category equal to 1, otherwise equal to 0 for the base category. Standard errors in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$