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Exploring the Agriculture-Nutrition Linkage in Northern Ghana

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Notices

Contents

Tables

Figures

ABSTRACT

Despite progresses over the last few decades, undernutrition is widespread across Africa south of the Sahara. While agricultural interventions have traditionally focused on enhancing yields of few staple crops, there is increased interest on the role of production diversity in enhancing the dietary quality of subsistence farm households. This study examines the effects of on-farm production diversity and productivity on household dietary diversity using primary data from Ghana, where a sustainable intensification program is being implemented. In addition, it assesses possible heterogeneity in the effect of production diversity by market access. Identification is based on instrumental variables – to account for possible simultaneity between production and consumption decisions – and propensity score weighting–to account for potential self-selection into the program. Both productivity and production diversity positively affect dietary diversity, with the effect of the latter getting stronger the farther away the daily market is, suggesting the importance of production diversity in settings with limited access to markets.

Keywords: production diversity, dietary diversity, market access, instrumental variables, propensity score weighting, Ghana

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ACRONYMS

DDI	Dietary diversity index
DDS	Dietary diversity score
GARBES	Ghana Africa RISING Baseline Evaluation Survey
IFPRI	International Food Policy Research Institute
IITA	International Institute of Tropical Agriculture
IV	Instrumental variables
IV-2SLS	Instrumental variables-two-stage least squares
IV-GLS	Instrumental variables-generalized least squares
IV-GMM	Instrumental variables-generalized method of moments
PDI	Production diversity index
PDS	Production diversity score
RISING	Research In Sustainable Intensification for the Next Generation
USAID	United States Agency for International Development

1. INTRODUCTION

Notwithstanding improvements over the last several decades, progress has been uneven and food and nutrition insecurity remains widespread. For example, between 2000 and 2016, the number of stunted children aged 0–59 months has declined from 198 to 155 million (28%) globally, with the rate of decline for Africa (from 38% to 31%) less than half that of Asia (38% to 24%) and Latin America and the Caribbean (18% to 11%) (UNICEF, WHO, and WB, 2017). In this context, the concept of hidden hunger has been introduced to describe instances where diets are deficient in crucial micronutrients such as vitamins and minerals that are essential for normal growth and cognitive development, especially during the first 1,000 days since conception (Burchi et al., 2011; Kennedy et al., 2007; Muthayya et al., 2013; von Grebmer et al., 2014). Hidden hunger is particularity rampant in settings where diets are dominated by starchy staples and lack enough nutrient-rich foods such as fruits and vegetables, legumes, and animal-source foods (Hodge, 2016; von Grebmer et al., 2014; World Bank, 2007).

Traditionally, agricultural interventions have had a narrow focus on increasing productivity of few staple crops and overall profitability, without much consideration on the linkages with nutrition and health (Bouis and Welch, 2010). Since the 1990s, agricultural interventions and strategies that aim to address health and nutrition explicitly have become more prominent (Ruel, 2001; World Bank, 2007). In this regard, two of the approaches that have been pursued to mitigate hidden hunger are increasing the availability and accessibility of nutritionally diverse foods–dietary diversification–(Burchi et al., 2011; Hoddinott and Yisehac, 2002), and the integration of more micronutrients into staple and complementary foods–biofortification–(Nilson and Piza, 1998; Rawat et al., 2013). However, biofortified staples cannot provide the full array of nutrients, and hence increasing dietary diversity could still be an important option for improving diets in subsistence settings (Johns and Eyzaguirre, 2007).

Nutrition and agricultural production are linked through myriad channels (Gillespie et al., 2012; Herforth and Harris, 2014; Hoddinott, 2012; Pandey et al., 2016). Especially for smallholder farm households in Africa south of the Sahara (SSA), agriculture is often the sole source of income and an important determinant of purchasing power (Berti et al., 2004; Kennedy and Peters, 1992). In these settings, food markets are often scattered and access to certain food groups (e.g., fruits and vegetables) can be challenging, regardless of purchasing power. In semi-autarkic environments, non-separable household models predict a direct link between production and consumption (Dillon and Barrett, 2014; Strauss and Thomas, 1995; World Bank, 2007).

While growing, the empirical evidence on the link between production diversity and dietary quality remains limited (Dillon et al., 2015). One strand of literature documents a positive association between the two among rural smallholders (Bellon et al., 2015; Herforth, 2010; Hirvonen and Hoddinott, 2014; Jones et al., 2014). Based on data from Kenya and Tanzania, Herforth (2010) finds a positive association between production diversity and household dietary quality while Jones et al. (2014) find similar trend among Malawian households, with a stronger association observed for female-headed households. Hirvonen and Hoddinott (2014) and Bellon et al. (2015) also document a positive association based on data from Ethiopia and South America, respectively.

However, a positive association between production diversity and dietary quality is not always observed empirically and the mediating role of market access remains ambiguous (Dillon et al., 2015; Kataki, 2002; ; Muller, 2009; Pellegrini and Tasciotti, 2014; Sibhatu et al., 2015). For instance, in a multi-country study covering Indonesia, Ethiopia, Kenya and Malawi, Sibhatu et al. (2015) find that on-farm production diversity is positively associated with dietary diversity in some cases but not all. The authors note that market access does not influence the link between the two and that nutritional effects of productivity are stronger than those of production diversity in most cases. Others note that increasing on-farm productivity and income is more important than increasing on-farm diversity (Smale et al., 2015), since the share of consumption coming from purchases has been increasing in recent years (Baiphethi and Jacobs, 2009).

Such mixed results imply that there is still much to be learned about the linkages between agriculture and diets, including on the relative importance of on-farm production diversity and productivity and on the role of markets. In addition, the empirical evidence coming from regions like

West Africa is relatively limited, in spite of the widespread food and nutrition insecurity (Saaka et al., 2015).

This study contributes to the literature by examining the agriculture–nutrition linkage using data from northern Ghana. Specifically, we assess the relative importance of productivity and production diversity in improving household dietary diversity, while at the same time assessing the role of market access. We find that both on-farm production diversity and productivity positively affect household dietary diversity. In addition, the effect of production diversity gets stronger the longer the travel time to the nearest daily market.

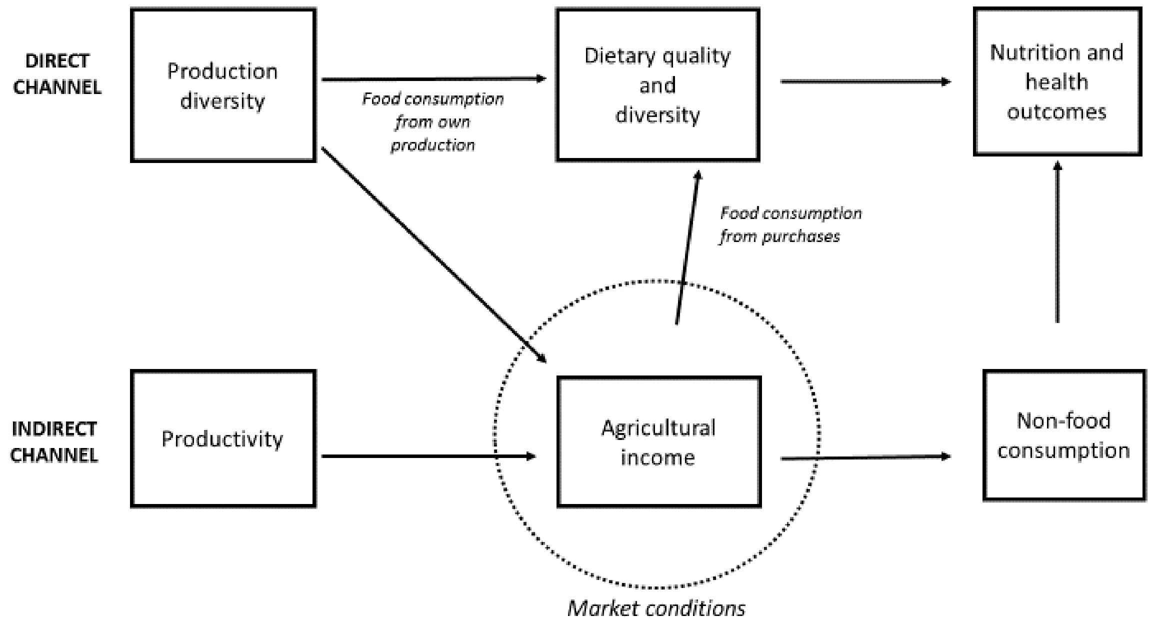
The rest of the paper is structured as follows. Section 2 describes the conceptual framework. Section 3 discusses the study setting and primary data used. Section 4 details the identification strategy. Section 5 presents and discusses the results. Section 6 concludes the paper.

2. CONCEPTUAL FRAMEWORK

Under perfect markets, production and consumption decisions are separable (Singh, Squire, and Strauss, 1986). In such settings, households first make production decisions to maximize income and subsequently make consumption decisions to maximize utility subject to budget constraints and given preferences and subjective discount rates (Jorgenson and Lau, 2000). Under this scenario, the diversity of crops grown and livestock bred only influence food consumption through their effects on total agricultural income. However, the literature has long established that the separable model is not suitable for describing household decision-making under imperfect markets. Market failures preclude the availability of certain items, regardless of household income, thereby making production and consumption decisions non-separable (de Janvry and Sadoulet, 2006; de Janvry et al., 1991; Liu et al., 2014; Singh et al., 1986).

In areas like northern Ghana, agriculture is expected to affect nutrition both through increased supply of own-produced food items (direct channel) and higher purchasing power as a result of increased productivity and agricultural income (indirect channel) as shown in Figure 2.1. The magnitude of the indirect channel in turn depends on the ability to generate higher market surplus as well as on the ease of access to food and non-food markets. We expect the direct channel to become more important as the physical access to markets gets more difficult and with increases in commodity prices, especially for net buyers.

Figure 2.1 Impact pathways from agriculture to nutrition



Source: Adapted from Herforth and Harris (2014).

3. STUDY SETTING AND DATA

This study was conducted as part of a research program called Africa Research In Sustainable Intensification for the Next Generation (Africa RISING[1]). The program is funded by the United States Agency for International Development (USAID) as part of the U.S. government's global hunger and food security initiative–Feed the Future– and is being implemented in six countries (Ghana, Mali, Ethiopia, Malawi, Tanzania, and Zambia) since 2012. Africa RISING aims to identify integrated technology options with the potential to increase productivity and improve nutrition, while at the same time conserving the natural resource base.

As of May 2014, the Ghana program was being implemented under the leadership of the International Institute of Tropical Agriculture (IITA) in 25 communities[2] in the Northern, Upper West, and Upper East regions of Ghana. During the initial years (2012–2013), it focused on a limited set of technologies: improved maize cultivars with fertilizer, improved cowpea cultivars with pesticides, and improved soybean cultivars with integrated soil fertility management practices. From the beginning, program implementers have stressed production diversification as one of the goals of the program.

Ghanaian cuisine is mainly composed by cereals, starchy roots and plantain and the main staples in the study area are maize, millet, sorghum and yam (FAO, 2009). Roots and tubers account for about 60% of the total value of home consumption in Ghana while cereals, vegetables, and legumes constitute 14%, 7%, and 5%, respectively (FAO, 2009). Vegetables and legumes such as okra, beans and groundnuts are often used to prepare sauces to complement the main dishes.

Due to the dominance of starches, dietary diversity remains low and the contribution of food groups other than cereals and starchy roots to the dietary energy supply has been around 28% since the 1960s (FAO, 2009). This high reliance on starchy foods and the low consumption of other food types has resulted in poor health conditions, particularly among children. For example, the prevalence of chronic

[1] Additional details about the program can be found here https://africa-rising.net/.
[2] Community represents the lowest administrative unit.

undernutrition among children under five years was 22% in 2009 (FAO, 2009), which showed little progress from the 30.6% that prevailed about three decades ago (Alderman, 1990).

Primary data for this study come from the Ghana Africa RISING Baseline Evaluation Survey (GARBES) (IFPRI, 2015) that gathered detailed socioeconomic data from 25 program and 25 control communities, the latter having similar agro-ecological conditions as the former.[3] Figure B.1 in the Appendix shows the spatial distribution of study communities. GARBES interviews were conducted between May 13 and July 3, 2014 with 1284 households, of which 462 are program beneficiaries and the rest are non-beneficiaries sampled from both program target and control communities. GARBES contains detailed information about agricultural production (crop and livestock) for the growing period April 2013 – December 2013 as well as a 7-day recall record of all the food items consumed inside the household.

We construct two measures of dietary diversity– household Dietary Diversity Score (DDS) and household Dietary Diversity Index (DDI). The DDS measures the number of different food groups consumed by the household during the reference period following Kenned et al. (2013) and Swindale and Bilinsky (2006).[4] Its value ranges from zero to twelve and has been found to be a good proxy of dietary quality, given its correlation with the diversity of micro-nutrient intake (positive) and malnutrition (negative) (Arimond and Ruel, 2004; Arimond et al., 2010; Moursi et al., 2008; Savy et al., 2005). The DDI is a simple count of unique food items consumed, without consideration of the food group to which they belong. By using these two complementary indicators of dietary diversity, the analysis will shed more light on the dynamics of dietary diversity in the region.

[3] Before the implementation of the program, the study region has been stratified based on length of growing period (LGP) and market access (MA) resulting in the following six strata: high LGP – high MA, high LGP – medium MA, low LGP – medium MA, medium-high LGP – low MA, medium-high LGP – medium MA, and medium-low LGP – medium MA. The cutoff points for LGP are as follows: low refers to <= 162 days, medium-low refers to 162 – 180 days, medium-high represents 181 – 190 days, and high represents >190 days. Low market access represents travel time of more than 200 minutes (one way) to the nearest town of at least 50, 000 people, medium market access represents travel time of 100 - 200 minutes, and high market access represents a travel time of less than 100 minutes.

[4] The following 12 food groups are considered in our household dietary diversity score: cereals; white tubers and roots; legumes, nuts, and seeds; vegetables; fruits; meat; eggs; fish and fish products; milk and milk products; sweets and sugars; oils and fats; and spices and beverages.

Production diversity is measured using two indicators that mirror those for dietary diversity– household Production Diversity Score (PDS) and Production Diversity Index (PDI). The PDS is a count of the number of food groups produced during the reference period while the PDI is a simple count of the total number of unique agricultural items produced. Since three of the food groups considered (sweets and sugars, oils and fats, spices and beverages) were not own produced, the production diversity score ranges from one to nine. Productivity is captured through cereal yield, given that the majority of the study households are cereal growers (98%), as opposed to, say, legume growers (74%) and vegetable growers (6%).

The main cereals produced are maize (91%), rice (47%), pearl millet (24%s) and sorghum (13%). Any observed effect of cereal productivity on dietary diversity does not rule out the existence of differential effects by crop. Nevertheless, we argue that cereal productivity is highly correlated with the productivity of other subsistence crops, and in our sample only a negligible percent of the households grows cash crops such as tobacco, cotton, and mango (less than 1%). Finally, access to markets is measured based on travel time (in minutes) to the nearest daily market using the usual mode of transport. This indicator allows us to capture both the physical distance to markets and household-specific constraints that may affect travel time.

Table 3.1 presents summary statistics by the three regions. Study households consume an average of 7.5 food groups and 11.2 food items, while they produce an average of 2.5 food groups and 4.7 food items. The average cereal yield is 781 kilograms per hectare (kg/ha), which is less than half of the national average of 1703 (kg/ha).[5] The Upper West region has the lowest cereal yield (672 kg/ha) while the Northern region has the least access to daily markets (18.5 minutes). The three regions are significantly different from each other in terms of the other socio-demographic aspects we control for in the analysis, thus offering some heterogeneity for more precise identification.

[5] Source is the 2014 World Bank World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators

Table 3.1 Descriptive summary

	Northern Region	Upper East region	Upper West region	Total
Dietary Diversity Score (1-12)	7.78***	7.02***	7.45	7.53
Dietary Diversity Index	11.3	11.75**	10.87**	11.23
Production Diversity Score (1-9)	2.55	2.17***	2.62***	2.51
Production Diversity Index	4.43***	4.54**	5.26***	4.74
Yield of cereals (kg/ha)	888.23***	707.44	672.13***	781.09
Time to the closest daily market (minutes)	18.53***	16.55	9.10***	14.91
Africa RISING participation (%)	0.30***	0.55***	0.37	0.37
Household size	9.93***	6.45***	7.91***	8.61
The head is female (%)	0.08***	0.30***	0.19**	0.16
The head is Christian (%)	0.10***	0.49***	0.59***	0.34
The head is Muslim (%)	0.85***	0.05***	0.31***	0.52
Number of females in the household excluding head	2.03***	0.94***	1.43***	1.63
Number of children in the household	2.04***	0.90***	1.22***	1.55
Age of the head (years)	48.67*	47.88	47.00*	47.95
Max. males years of education in the household	5.76***	7.13***	6.37	6.21
Max. females years of education in the household	2.98***	5.65***	4.00	3.81
Share of food consumption from own production (%)	36.40***	29.63***	48.86***	39.51
Total land size (ha)	4.01***	1.68***	2.76***	3.16
Non-agricultural wealth (index)	-0.02	-0.12*	0.06*	-0.01
Number of off-farm income sources	0.95	0.83**	1.05***	0.96
Average number of plots per parcel	1.54***	1.51***	2.29***	1.79
Interaction with farmers groups and extensions	0.72***	0.77***	0.55***	0.67
Household uses chemical fertilizer (%)	0.84***	0.76	0.72***	0.78

Source: IFPRI, 2015.

Notes: * significant at 10%; ** significant at 5%; *** significant at 1%.

4. IDENTIFICATION STRATEGY

When considering the agriculture-nutrition linkage, one needs to account for the possible simultaneity between production and consumption decisions. In addition, the underlying household characteristics that affect selection into the Africa RISING program can affect both agronomic and nutritional outcomes. To address these two identification challenges, we combine instrumental variables (IV) with propensity score weighting.

The main model we estimate to identify the determinants of household dietary diversity is shown in Equation (1).

$$DD_i = \alpha + \beta_1 PD_i + \beta_2 CY_i + \beta_3 MA_i + \delta_1 Part + \mathbf{\Gamma}'\boldsymbol{X}_{1i} + \boldsymbol{r} + \varepsilon_i \quad (1)$$

where *i* indexes household; *DD* measures dietary diversity; *PD* measures farm production diversity; *CY* captures the logarithm of cereal yield; *MA* measures access to the nearest daily market; *Part* is an indicator for participation in Africa RISING program, $\boldsymbol{X}_1$ is a matrix of household level controls including family size, gender and age of the household head as well as an indicator for being a Christian or Muslim (as opposed to traditional or no religion), the number of children and adult women, the highest educational attainment among adult members, the size of land operated by the household, non-agricultural asset-based wealth index[6], the number of off-farm income sources, and the share of total food consumption coming from own production; $\boldsymbol{r}$ is a vector of region fixed effects; and ε_i is the model error term.

We instrument PD using the average number of cultivated plots per parcel and an indicator for whether the household has had interactions with farmers groups and extension agents in the preceding year. Productivity is instrumented using indicators for chemical fertilizer use and interaction with farmers groups and extension agents. We argue that these instruments, while correlated with the suspect endogenous regressors, are unlikely to be correlated with dietary outcomes other than through their

[6] This index is constructed using factor analysis (principal-component factor method), following Filmer and Pritchett (2001), based on household's ownership of various non-agricultural durable assets such as radio, television, mobile phone.

effects on agricultural production. Since Equation (1) is over-identified, we perform the standard tests of exogeneity to validate the instruments.

As a robustness check, we employ three different estimators: IV based on the two-stage least squares estimator (IV-2SLS), IV using the generalized method of moments (IV-GMM) and Poisson-IV-GMM. The 2SLS model is a special case of the IV-GMM that can be applied when the error terms are independently and identically distributed. When errors are heteroskedastic, on the other hand, IV-2SLS estimates would remain consistent but the standard errors would be under-estimated resulting in invalid diagnostic tests (Baum et al., 2003). The Poisson IV-GMM is our preferred model since it accounts for the count nature of the outcome variables.

Estimates from Equation (1) can still be prone to biases if there are underlying factors that systematically affect the decision to participate in Africa RISING program that are also correlated with production and consumption decisions. To address this, we first estimate a probit model of selection to recover the propensity score – *Pscore*– as shown in Equation (2).

$$Part_i = \alpha + \boldsymbol{\Theta}'_1 \boldsymbol{X}_{2i} + \mu_i \tag{2}$$

where $\boldsymbol{X}_2$ is a vector of household-level covariates that could affect participation decision but are unlikely to have been affected by the program. The propensity score obtained from Equation (2) is used to estimate Equation (1) using IV Generalized Least Squares (IV GLS), where the weight for observation i is $1/Pscore_i$ if i is a program participant and $1/(1 - Pscore_i)$ if otherwise. Observations falling outside the base of the common support are excluded to insure comparability.

To examine possible heterogeneity by market access, we re-estimate Equation (1) by including interaction terms between travel time to daily market and production diversity.

$$DD_i = \alpha + \beta_1 PD_i + \beta_2 CY_i + \beta_3 MA_i + \beta_4 PD_i * MA_i + \delta_1 Part + \boldsymbol{\Gamma}' \boldsymbol{X}_{3i} + \boldsymbol{r} + \varepsilon_i \tag{3}$$

Since the interaction term could potentially be endogenous as well (it is potentially composed of an endogenous variable), we create two additional instruments by interacting market access with the number of plots per parcel and interactions with farmers groups. A statistically significant and positive $\widehat{\beta_4}$

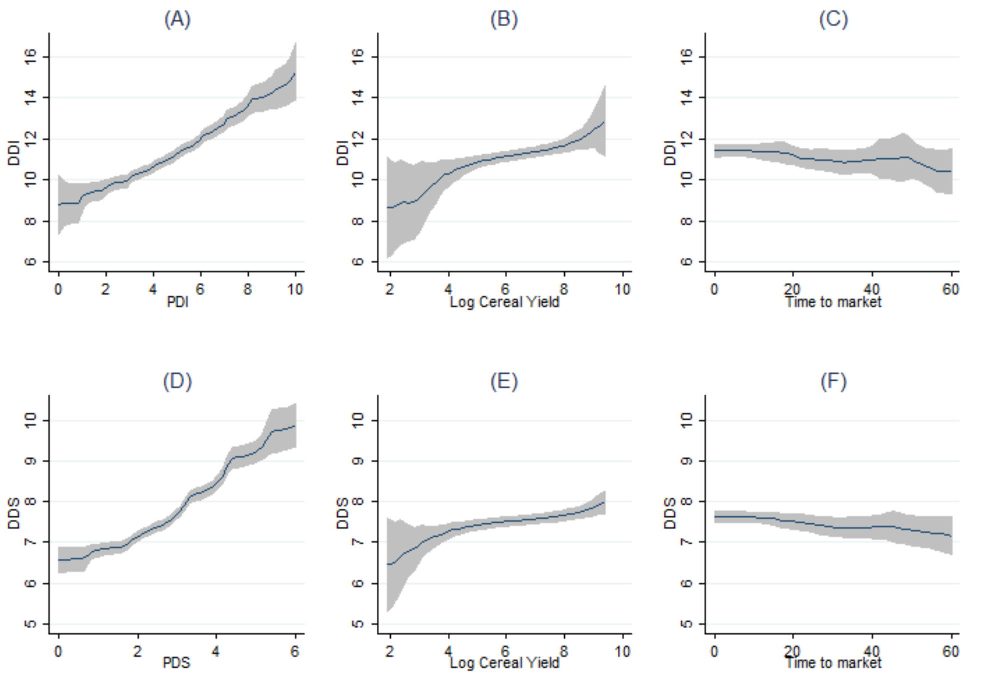
indicates that the longer the travel time, the greater the influence of production diversity on household dietary diversity. Robust standard errors from all regressions are clustered at the village level.

5. RESULTS AND DISCUSSION

Before presenting estimation results, we non-parametrically explore the bivariate relationship between the indicators of productivity, production diversity, market access, and dietary diversity in Figure 5.1. The relationship between DDI on the one hand and the three variables of interest – PDI, cereal yield, and market access– is shown in panels A, B and C, respectively. Panel D, E and F of Figure 5.1 show the relationship between household DDS and the same three variables of interest.

A clear linear and positive association is observed between production diversity and dietary diversity, indicating the importance of own-produced food for household dietary diversity (Figure 5.1, panels A and D). A weaker positive relationship is also observed between dietary diversity and the log of cereal yield (Figure 5.1, panels B and E), with wider 95% confidence bands observed at lower yield level. Finally, a tenuous negative relationship is shown between dietary diversity and distance to market, that gets more imprecise with travel time (Figure 5.1, panels C and F). The latter trend could be explained by the fact that some households may be able or willing to travel farther to maintain their desired level of dietary diversity while others renounce, introducing more noise.

Figure 5.1 Dietary diversity, production diversity, and market access



Source: Authors' calculations

Table A.1 in the appendix reports the results of the propensity score probit model. Participation in Africa RISING appears to have a strong gender component, with female headed households more likely to participate, *ceteris paribus*. Other positive predictors of program participation include ownership of at least one parcel within 15 minutes of travel from the homestead, having interactions with farmers groups or extension agents, and agricultural wealth. On the other hand, the bigger the land size and the higher the stock of non-agricultural assets, the lower the likelihood of participation, suggesting possible program targeting towards smallholders and the poor.

Figures B.2 and B.3 in the Appendix show the distribution of the propensity score by program participation status before and after the exclusion of the 22 households that fall outside the base of the common support. The model performs well in predicting some of the variation in participation status without being too precise, thus allowing us to recover comparability between the two groups (see Heckman et al., 1997 for general discussion). Since the propensity score ranges between 0.04 and 0.93, we do not encounter issues of excessively large weights at the margins of the distribution, which poses a challenge when probabilities are too close to zero or one (Khan and Tamer, 2010). To ensure that the model solves for observable differences due to program targeting, we check the balancing of covariates before and after weighting with the obtained propensity score. Table A.2 in the Appendix summarizes the results and shows that the observed differences in means between the two groups disappear after weighting.

Estimation results from the main model (Equation (1)) are summarized in Table 5.1. The 2SLS and IV-GMM models pass all the standard IV diagnostic tests – the two suspect endogenous variables are indeed endogenous (Hausman test), and the instruments pass both the weakness test (Kleibergen-Paap) and the over-identification test (Sargan-Hansen). It is more difficult to test these elements with the IV-Poisson-GMM, thus we only report the over-identification test of the instruments, that they pass. The obtained coefficients are consistent across specifications and support our initial hypotheses: both production diversity and productivity positively contribute to household dietary diversity. In addition, given that the correlation between the production diversity indicators and cereal yield is low (0.06 for the production diversity index and 0.10 for the production diversity score), we are confident that the two effects are separately identified. As would be expected, distance to markets decreases household dietary diversity.

As has previously been documented (Doss, 2005; Duflo and Udry, 2004; Katz, 2007; Malapit et al., 2013; Malapit and Quisumbing, 2015; Sraboni et al., 2014), the presence of females in the household is positively correlated with dietary diversity, and especially so when the household head is female. This may be capturing gender differences in decision-making regarding income use and household consumption. The observed correlation may also have been driven by gender differences in the likelihood of consuming food outside the house, given that the dietary diversity indicators are constructed based on food consumed inside the house.

For both indicators of dietary diversity, the higher the educational attainment of adult females, the more diverse diets are, while male education is significant only in the dietary diversity index model with magnitude weaker than of female education. The number of children is also positively associated with dietary diversity and so is physical capital (assets, land, and income diversification), as expected. Program participation, on the other hand, did not have a significant impact on dietary diversity of the beneficiary households. This result is not surprising, since the food consumption data was collected only one season after the beginning of the program with relatively short time lapse impact nutrition.

The larger the share of food consumption that comes from own production, the lower the dietary diversity. This confirms that on-farm production alone is insufficient to ensure quality diets, despite its positive contribution (Rais et al., 2009). Farm diversification as a food security strategy needs to be complemented with efforts to improve access to (food) markets. The regional heterogeneity shown in the descriptive summary table (Table 3.1) is confirmed by the regression results where households in the Upper West region generally have a less diverse diet compared with their counterparts in the Northern region (the omitted category). Nonetheless, this pattern holds only when dietary diversity is measured using the dietary diversity index.

Table 5.1 Effects of productivity and production diversity on household dietary diversity

	Dietary Diversity Index			Dietary Diversity Score (1-12)		
	2SLS	IV GMM	POISSON IV GMM	2SLS	IV GMM	POISSON IV GMM
Production Diversity Index/ Production Diversity Score	1.558***	1.504***	0.128***	1.011***	0.982***	0.128***
	(0.353)	(0.346)	(0.031)	(0.276)	(0.275)	(0.038)
Log of cereal yield (ton/ha)	3.099***	3.284***	0.358***	1.126**	1.203**	0.182**
	(0.948)	(0.918)	(0.119)	(0.473)	(0.467)	(0.079)
Time to the closest daily market (minutes)	-0.022***	-0.021***	-0.002***	-0.013***	-0.013***	-0.002***
	(0.007)	(0.007)	(0.001)	(0.003)	(0.003)	(0.000)
Africa RISING participation	-0.105	-0.148	-0.002	-0.058	-0.086	-0.009
	(0.315)	(0.311)	(0.029)	(0.156)	(0.154)	(0.022)
Household size	-0.301***	-0.296***	-0.028***	-0.124***	-0.123***	-0.017***
	(0.086)	(0.086)	(0.008)	(0.038)	(0.038)	(0.006)
The head is female	1.789***	1.732***	0.148***	0.768***	0.742***	0.099***
	(0.426)	(0.420)	(0.042)	(0.209)	(0.207)	(0.030)
The head is Christian	0.107	0.147	0.025	0.285*	0.298*	0.045**
	(0.503)	(0.500)	(0.046)	(0.165)	(0.164)	(0.023)
The head is Muslim	0.074	0.049	0.019	0.411**	0.397*	0.060**
	(0.551)	(0.550)	(0.054)	(0.204)	(0.204)	(0.029)

Table 5.1 Continued

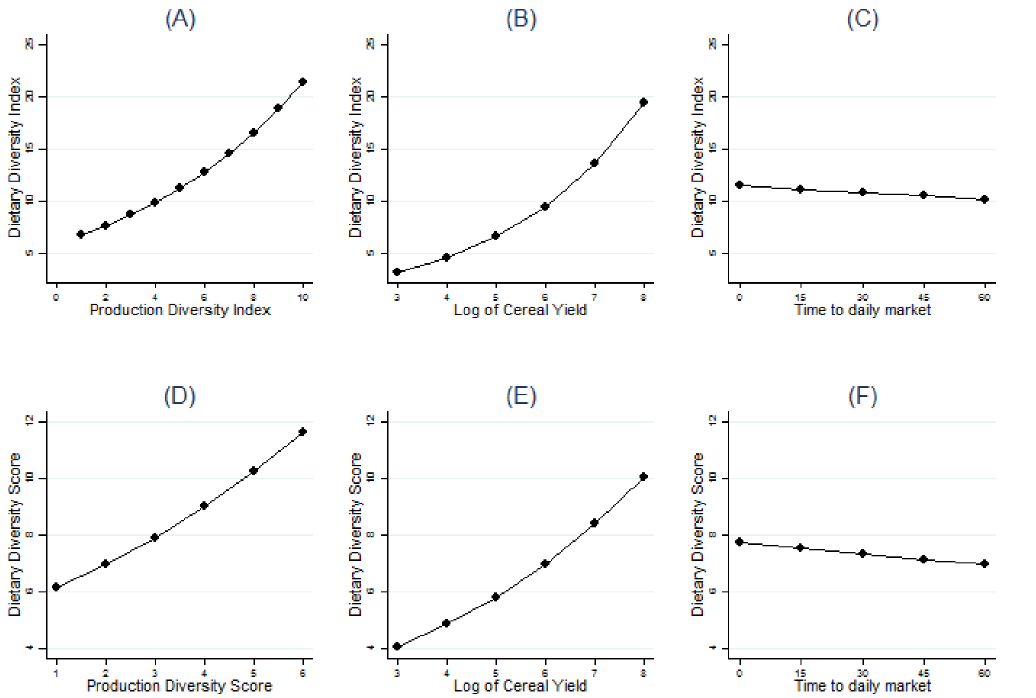
	Dietary Diversity Index			Dietary Diversity Score (1-12)		
	2SLS	IV GMM	POISSON IV GMM	2SLS	IV GMM	POISSON IV GMM
Number of females in the house excluding the head	0.247**	0.220*	0.014	0.090	0.071	0.007
	(0.122)	(0.117)	(0.011)	(0.059)	(0.056)	(0.008)
Number of children in the household	0.390**	0.398**	0.038**	0.128*	0.146**	0.021*
	(0.165)	(0.165)	(0.017)	(0.075)	(0.073)	(0.012)
Age of the head (years)	-0.009	-0.008	-0.001	-0.010**	-0.009**	-0.001**
	(0.010)	(0.010)	(0.001)	(0.004)	(0.004)	(0.001)
Max. males years of education in the household	0.058**	0.064**	0.006***	0.005	0.010	0.002
	(0.027)	(0.026)	(0.002)	(0.013)	(0.012)	(0.002)
Max. females years of education in the household	0.083***	0.080***	0.008**	0.034**	0.031**	0.005*
	(0.031)	(0.030)	(0.003)	(0.015)	(0.015)	(0.002)
Share of food consumption from own production	-0.038***	-0.038***	-0.004***	-0.010**	-0.010**	-0.001**
	(0.010)	(0.010)	(0.001)	(0.005)	(0.005)	(0.001)
Total land size (ha)	0.055	0.046	0.008	0.097***	0.093***	0.013***
	(0.094)	(0.094)	(0.008)	(0.035)	(0.035)	(0.004)
Non-agricultural wealth (index)	0.450**	0.406*	0.016	0.282***	0.262***	0.029**
	(0.223)	(0.215)	(0.023)	(0.092)	(0.090)	(0.013)
Number of off-farm income sources	0.292*	0.291*	0.025	0.119	0.126	0.016
	(0.177)	(0.177)	(0.017)	(0.089)	(0.089)	(0.012)
Upper East region	-0.607	-0.552	-0.037	-0.430	-0.414	-0.057
	(0.821)	(0.818)	(0.077)	(0.360)	(0.360)	(0.055)
Upper West region	-1.295**	-1.080**	-0.066	-0.267	-0.190	-0.012
	(0.542)	(0.467)	(0.049)	(0.250)	(0.238)	(0.034)
Constant	-12.904**	-13.990**	-0.282	-1.204	-1.672	0.644
	(5.986)	(5.823)	(0.772)	(2.963)	(2.927)	(0.499)
Observations	1,222	1,222	1,222	1,222	1,222	1,222
R2	-0.061	-0.093		0.119	0.096	
R2 - uncentered	0.883	0.879		0.944	0.943	
Hausman endogeneity test	8.799	8.799		4.951	4.951	
Hausman P-value	0.012	0.012		0.084	0.084	
Kleibergen-Paap rk LM statistic	20.065	20.065		20.768	20.768	
Kleibergen-Paap P-value	0.000	0.000		0.000	0.000	
Sargan-Hansen overidentification test	0.610	0.610	1.271	1.054	1.054	1.251
Sargan's P-value	0.435	0.435	0.260	0.305	0.305	0.263
F test of overall model fit	10.131	12.636		13.297	15.297	
F test P-value	0.000	0.000		0.000	0.000	

Notes: ***; **; and * represent significance at the 1%, 5%, and 10% level, respectively. Reported are robust standard errors clustered at the community level. Instruments for production diversity and cereal yield are average number of plots per parcel, contact with farmers groups or extension agents, and use of chemical fertilizers. Northern region is the omitted category.

From the first stage results reported in Table A.3 in the Appendix, we note that the average plots per parcel and interaction with farmers groups or extension services are significantly and positively correlated with both measures of production diversity, while the use of fertilizer and the interaction with farmers groups or extension services are significantly and positively correlated with cereal yield. These results give us further confidence in the strength of our instruments. Furthermore, program participation is associated with significantly wider production diversity, both in terms of food items and food groups produced, while it does not show any effect on yield. Female headed households have lower cereal productivity and produce fewer food groups, while larger land holdings are associated with more production diversity but are not correlated with greater productivity. Finally, older household heads are associated with less production diversity.

Results from the IV Poisson regression are likely to be the most accurate since the model accounts for the count nature of the outcome variables. However, the interpretation of the magnitude of the Poisson coefficients is not straightforward, thus we use the model to predict the expected dietary diversity obtained at different levels of production diversity, cereal yield and distance to daily markets, other conditioning variables evaluated at the mean. Figure 5.2 reports the results on the dietary diversity index (panels A, B and C) and on the dietary diversity score (panels D, E and F). Producing one additional food group – while all the other variables kept at their mean – increases the predicted dietary diversity score by roughly 1 group. When cereal productivity increases by one point in natural logarithm (grows by 2.7 times), the predicted dietary diversity index raises by approximately 1 food group at low levels of yield, and reaches almost 2 food groups at high levels of yield. Finally, a 15-minute increase in distance to daily markets has only a marginally negative effect on dietary diversity (roughly 0.2 food groups consumed).

Figure 5.2 Predicted dietary diversity (from the Poisson model)



Source: Authors' calculations

Finally, regression results from the interaction model (Equation (3)) are reported in Table 5.2, with the model passing the standard IV tests reported at the bottom of the table. We find that the longer the travel time to the nearest daily market, the greater the effect of production diversity on household dietary diversity. This is consistent with our hypothesis that the reliance on own-produced foods increases with the distance to markets. The other coefficient estimates are consistent with the results from the main model summarized in Table 5.1. First stage results for the interaction model are shown in Appendix Table A.4.

Table 5.2 Effects of productivity, production diversity, and market access on dietary diversity

	Dietary Diversity Index			Dietary Diversity Score (1-12)		
	2SLS	**IV GMM**	**POISSON IV GMM**	**2SLS**	**IV GMM**	**POISSON IV GMM**
Production Diversity Index/ Production Diversity Score	1.154***	1.131***	0.094***	0.679*	0.670*	0.088*
	(0.388)	(0.375)	(0.036)	(0.366)	(0.366)	(0.050)
Production Diversity * Travel time to closest daily market	0.030**	0.027**	0.002**	0.019*	0.018*	0.002
	(0.012)	(0.012)	(0.001)	(0.011)	(0.011)	(0.002)
Log of cereal yield (ton/ha)	3.111***	3.306***	0.361***	1.130**	1.068**	0.157**
	(0.909)	(0.876)	(0.110)	(0.458)	(0.433)	(0.068)
Time to the closest daily market (minutes)	-0.166***	-0.151***	-0.014**	-0.063**	-0.059**	-0.008*
	(0.060)	(0.056)	(0.006)	(0.028)	(0.028)	(0.004)
Africa RISING participation	-0.121	-0.143	-0.000	-0.071	-0.094	-0.010
	(0.301)	(0.300)	(0.029)	(0.155)	(0.154)	(0.021)
Household size	-0.308***	-0.303***	-0.028***	-0.123***	-0.114***	-0.015***
	(0.087)	(0.086)	(0.008)	(0.038)	(0.036)	(0.005)
The head is female	1.893***	1.877***	0.153***	0.811***	0.790***	0.106***
	(0.454)	(0.423)	(0.042)	(0.226)	(0.225)	(0.030)
The head is Christian	0.164	0.192	0.035	0.269*	0.300**	0.046**
	(0.478)	(0.468)	(0.043)	(0.146)	(0.143)	(0.020)
The head is Muslim	0.090	0.061	0.024	0.358*	0.394**	0.061**
	(0.542)	(0.540)	(0.053)	(0.202)	(0.195)	(0.028)
Number of females in the household excluding head	0.254**	0.225*	0.015	0.109*	0.096	0.011
	(0.126)	(0.120)	(0.012)	(0.062)	(0.059)	(0.008)
Number of children in the household	0.388**	0.399**	0.036**	0.118	0.119*	0.016*
	(0.166)	(0.165)	(0.017)	(0.075)	(0.068)	(0.009)
Age of the head (years)	-0.013	-0.012	-0.001	-0.011***	-0.010***	-0.002***
	(0.011)	(0.010)	(0.001)	(0.004)	(0.004)	(0.001)
Max. males years of education in the household	0.048*	0.053**	0.005**	0.003	0.007	0.001
	(0.026)	(0.025)	(0.002)	(0.014)	(0.013)	(0.002)
Max. females years of education in the household	0.078***	0.075***	0.008**	0.030**	0.027*	0.004*
	(0.029)	(0.028)	(0.003)	(0.015)	(0.014)	(0.002)
Share of food consumption from own production	-0.038***	-0.039***	-0.004***	-0.010**	-0.010**	-0.001**
	(0.010)	(0.010)	(0.001)	(0.005)	(0.005)	(0.001)
Total land size (ha)	0.082	0.078	0.011	0.110***	0.107***	0.014***
	(0.092)	(0.092)	(0.008)	(0.038)	(0.038)	(0.005)
Non-agricultural wealth (index)	0.383*	0.338	0.009	0.259***	0.238**	0.026**
	(0.232)	(0.226)	(0.024)	(0.098)	(0.097)	(0.013)
Number of off-farm income sources	0.349*	0.346*	0.030	0.159	0.172*	0.021
	(0.194)	(0.193)	(0.019)	(0.099)	(0.098)	(0.013)

Table 5.2 Continued

	Dietary Diversity Index			Dietary Diversity Score (1-12)		
	2SLS	**IV GMM**	**POISSON IV GMM**	**2SLS**	**IV GMM**	**POISSON IV GMM**
Upper East region	-0.604	-0.457	-0.037	-0.399	-0.312	-0.038
	(0.788)	(0.733)	(0.070)	(0.356)	(0.347)	(0.054)
Upper West region	-1.287**	-1.111**	-0.061	-0.280	-0.176	-0.012
	(0.545)	(0.492)	(0.051)	(0.249)	(0.233)	(0.033)
Constant	-10.881*	-12.110**	-0.129	-0.319	-0.124	0.897**
	(5.598)	(5.377)	(0.703)	(2.873)	(2.783)	(0.441)
Observations	1,222	1,222	1,222	1,222	1,222	1,222
R2	-0.083	-0.111		0.110	0.133	
R2 - uncentered	0.880	0.877		0.944	0.945	
Hausman endogeneity test	11.201	11.201		5.746	5.746	
Hausman P-value	0.011	0.011		0.125	0.125	
Kleibergen-Paap rk LM statistic	20.146	20.146		20.849	20.849	
Kleibergen-Paap P-value	0.000	0.000		0.000	0.000	
Sargan-Hansen overidentification test	0.725	0.725	1.148	1.417	1.417	1.657
Sargan's P-value	0.696	0.696	0.563	0.492	0.492	0.437
F test of overall model fit	12.378	16.043		19.400	20.765	
F test P-value	0.000	0.000		0.000	0.000	

Notes: ***; **; and * represent significance at the 1%, 5%, and 10% level, respectively. Reported are robust standard errors clustered at the community level. Instruments for production diversity and cereal yield are average number of plots per parcel, contact with farmers groups or extension agents, use of chemical fertilizers and interactions with travel time to nearest daily market. Northern region is the omitted category.

6. CONCLUSION

Despite progresses made over the last several decades, food and nutrition insecurity is still widespread in developing regions like Africa south of the Sahara (SSA). In 2015, the prevalence of stunting among children under five years of age was the highest in Africa (38%), followed by South-East Asia (33%) (WHO, 2016). Diversification of agricultural production is among the strategies that are pursued to help improve the dietary diversity and quality of smallholder farm households.

This study focuses on north Ghana (Upper East, Upper West and Northern regions) –an area characterized by high poverty rate and food and nutrition insecurity–to empirically examine the agriculture-nutrition linkage through two channels–direct and indirect. The direct channel operates through the consumption of own-produced foods, i.e., on-farm diversification, while the indirect channel operates through agricultural income, i.e., higher productivity. In addition, we examine potential heterogeneity in the strength of the direct channel by market access.

We find that both productivity and on-farm production diversity positively affect household dietary diversity, with the effect of the latter getting stronger the longer the travel time to the nearest daily market. We also find that women's education and responsibility within the household play have significant positive effect on household dietary diversity, suggesting the importance of incorporating gender dimensions into interventions that aim to promote nutrition security. This study contributes to the growing empirical evidence on the agriculture-nutrition nexus using data from West Africa, a region with relatively fewer relevant empirical studies.

APPENDIX A: TABLES

Table A.1 Estimates of the selection model

	Africa RISING Participation
	(Probit)
Household size	0.034*
	(0.019)
The head is female	0.344***
	(0.111)
Age of the head	0.005*
	(0.003)
Head=married/cohabiting	-0.001
	(0.116)
Max males years of education in the household	-0.003
	(0.009)
Max females years of education in the household	0.009
	(0.009)
The head is Muslim	-0.001
	(0.229)
The head is Christian	0.159
	(0.170)
Number of children in the household	0.001
	(0.039)
The closest parcel is at less than 15 minutes distance	0.275**
	(0.113)
Frequent interactions with farmers groups and extensions	0.914***
	(0.113)
Total land size (Ha)	-0.075***
	(0.029)
Agricultural wealth index without land	0.165***
	(0.061)
Non-agr. wealth index	-0.168**
	(0.067)
Distance to basic services index	-0.011
	(0.061)
Altitude	0.002
	(0.002)
Constant	-2.027***
	(0.499)
N. obs	1,255
Adjusted R2	0.138

note: .01 - ***; .05 - **; .1 - *;
Standard errors clustered at the village level

Table A.2 Balancing of covariates with p-score weighting

	Without P-Score Weighting		With P-Score Weighting	
	Non-Participants	Participants	Non-Participants	Participants
Household size	8.34**	9.06**	9	8.72
The head is female	0.12***	0.22***	0.17	0.16
Age of the head	47.30**	49.06**	48.03	47.85
Head=married/cohabiting	0.9	0.89	0.9	0.9
Max males years of education in the household	5.99*	6.59*	6.21	5.97
Max females years of education in the household	3.52***	4.31***	3.85	3.59
The head is Muslim	0.56***	0.45***	0.52	0.53
The head is Christian	0.30***	0.40***	0.33	0.33
Number of children in the household	1.51	1.61	1.66	1.63
The closest parcel is at less than 15 minutes distance	0.38***	0.53***	0.44	0.42
Frequent interactions with farmers groups and extensions	0.57***	0.85***	0.68	0.67
Total land size (Ha)	3.33***	2.88***	3.15	3.21
Agricultural wealth index without land	-0.06***	0.16***	0.07	0.05
Non-agr. wealth index	0	-0.01	0	0.01
Distance to basic services index	0	0	0	-0.01
Altitude	231.78**	240.31**	234.91	235.19

* significant at 10%; ** significant at 5%; *** significant at 1%

Table A.3 First-stage regression results of the main model

	Production Diversity Index	Production Diversity Score (1-12)	Log of Cereal Yield
Average number of plots per parcel	0.388***	0.216***	-0.044
	(0.051)	(0.030)	(0.032)
Frequent interactions with farmers groups and extensions	0.339**	0.175***	0.251***
	(0.136)	(0.067)	(0.061)
The household uses chemical fertilizer	0.131	0.046	0.342***
	(0.119)	(0.065)	(0.060)
Time to the closest daily market (min)	0.003	0.004**	0.000
	(0.003)	(0.002)	(0.001)
AR participation	0.221**	0.204***	-0.077
	(0.090)	(0.062)	(0.059)
Household size	0.036**	0.015	0.027
	(0.015)	(0.014)	(0.017)
The head is female	-0.156	-0.183***	-0.214***
	(0.127)	(0.067)	(0.073)
The head is Christian	0.020	0.026	-0.025
	(0.145)	(0.096)	(0.078)
The head is Muslim	-0.473**	-0.061	0.121
	(0.190)	(0.132)	(0.103)
Number of females in the household excluding head	-0.007	0.022	-0.026
	(0.046)	(0.022)	(0.022)
Number of children in the household	-0.034	0.013	0.002
	(0.039)	(0.035)	(0.037)
Age of the head	-0.010***	-0.005***	-0.001
	(0.003)	(0.002)	(0.002)
Max males years of education in the household	-0.004	0.009	-0.004
	(0.010)	(0.006)	(0.005)
Max females years of education in the household	-0.006	-0.008	-0.007
	(0.010)	(0.007)	(0.005)
Share of food consumption from own production	0.016***	0.008***	0.004***
	(0.003)	(0.001)	(0.001)
Total land size (Ha)	0.122***	0.023	-0.018
	(0.033)	(0.015)	(0.016)
Non-agr. wealth index	0.028	-0.033	0.080**
	(0.060)	(0.030)	(0.038)
Number of off-farm income sources	0.047	0.097**	0.012
	(0.068)	(0.039)	(0.027)
a1==Upper East region	0.145	-0.252	0.120
	(0.236)	(0.198)	(0.150)
a1==Upper West region	0.212	-0.150	-0.045
	(0.216)	(0.130)	(0.107)
Constant	2.992***	1.534***	5.754***
	(0.359)	(0.202)	(0.182)
Obs.	1,222	1,222	1,222

note: .01 - ***; .05 - **; .1 - *;
Fixed effects for regions included. Reported are robust standard errors clustered at the village level.

Table A.4 First-stage regression results of the interaction model

	Production Diversity Index	Production Diversity Index * Time to market	Production Diversity Score (1-12)	Production Diversity Score * Time to market	Log of Cereal Yield
Average number of plots per parcel	0.358***	-2.412**	0.172***	-1.512***	-0.042
	(0.068)	(1.106)	(0.031)	(0.542)	(0.039)
Frequent interactions with farmers groups and extensions	0.349*	3.291	0.215***	1.989	0.253***
	(0.180)	(2.662)	(0.081)	(1.514)	(0.085)
The household uses chemical fertilizer	0.129	0.767	0.043	0.842	0.343***
	(0.119)	(2.745)	(0.064)	(1.983)	(0.060)
Average number of plots per parcel * Time to market	0.002	0.650***	0.004***	0.409***	-0.000
	(0.003)	(0.127)	(0.001)	(0.055)	(0.001)
Frequent interactions with farmers groups and extensions * Time to market	-0.001	0.116	-0.003	0.026	-0.000
	(0.005)	(0.334)	(0.002)	(0.133)	(0.003)
Time to the closest daily market (min)	-0.001	3.553***	-0.001	1.920***	0.000
	(0.006)	(0.270)	(0.003)	(0.131)	(0.004)
AR participation	0.222**	3.421	0.207***	4.044***	-0.077
	(0.089)	(2.646)	(0.061)	(1.145)	(0.058)
Household size	0.036**	0.726**	0.016	0.250	0.027
	(0.015)	(0.358)	(0.014)	(0.297)	(0.017)
The head is female	-0.150	-3.681	-0.174**	-4.188*	-0.214***
	(0.128)	(3.331)	(0.068)	(2.397)	(0.073)
The head is Christian	0.021	-1.487	0.030	1.373	-0.025
	(0.145)	(3.443)	(0.094)	(2.314)	(0.077)
The head is Muslim	-0.470**	-6.831	-0.051	1.885	0.121
	(0.187)	(4.940)	(0.129)	(3.271)	(0.104)
Number of females in the household excluding head	-0.008	-0.659	0.020	-0.809*	-0.026
	(0.046)	(0.694)	(0.022)	(0.484)	(0.022)
Number of children in the household	-0.031	0.338	0.017	1.207*	0.002
	(0.038)	(1.065)	(0.036)	(0.668)	(0.036)
Age of the head	-0.010***	-0.034	-0.005***	-0.007	-0.001
	(0.003)	(0.059)	(0.002)	(0.047)	(0.002)
Max males years of education in the household	-0.004	0.290*	0.009	0.295**	-0.004
	(0.010)	(0.162)	(0.006)	(0.126)	(0.005)
Max females years of education in the household	-0.006	0.068	-0.009	0.031	-0.007
	(0.010)	(0.216)	(0.007)	(0.151)	(0.005)
Share of food consumption from own production	0.016***	0.221***	0.008***	0.155***	0.004***
	(0.003)	(0.052)	(0.001)	(0.033)	(0.001)

Table A.4 Continued

	Production Diversity Index	Production Diversity Index * Time to market	Production Diversity Score (1-12)	Production Diversity Score * Time to market	Log of Cereal Yield
Total land size (Ha)	0.122***	0.607	0.023	-0.347	-0.018
	(0.032)	(0.495)	(0.015)	(0.332)	(0.016)
Non-agr. wealth index	0.027	2.374	-0.034	0.483	0.081**
	(0.060)	(1.976)	(0.029)	(0.880)	(0.038)
Number of off-farm income sources	0.048	-1.027	0.098**	-0.190	0.012
	(0.068)	(1.445)	(0.040)	(0.937)	(0.027)
a1==Upper East region	0.142	0.820	-0.256	-6.399	0.120
	(0.234)	(5.901)	(0.193)	(4.093)	(0.150)
a1==Upper West region	0.221	3.920	-0.130	-0.646	-0.045
	(0.214)	(3.830)	(0.128)	(2.543)	(0.112)
Constant	3.040***	-13.975*	1.588***	-11.056**	5.749***
	(0.384)	(7.542)	(0.192)	(4.786)	(0.193)
Obs.	1,222	1,222	1,222	1,222	1,222

note: .01 - ***; .05 - **; .1 - *;
Fixed effects for regions included. Reported are robust standard errors clustered at the village level.

APPENDIX B: FIGURES

Figure B.1 Study communities of northern Ghana

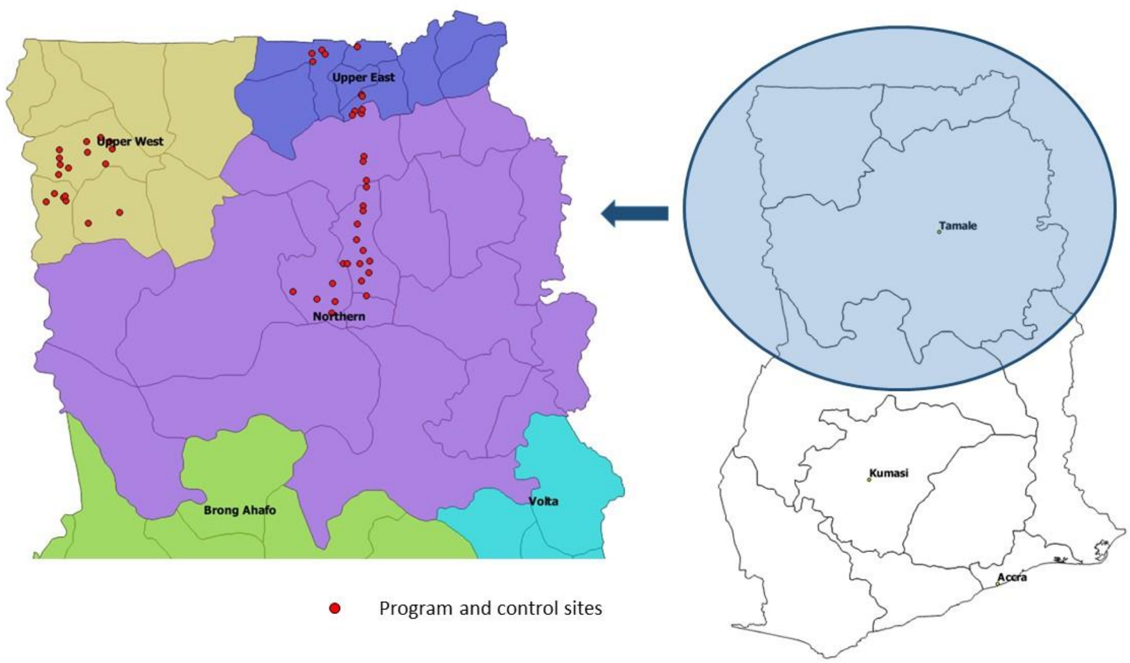


Figure B.2 Distribution P-score before trimming

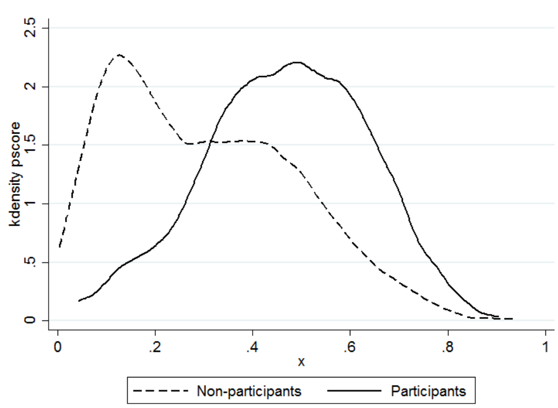
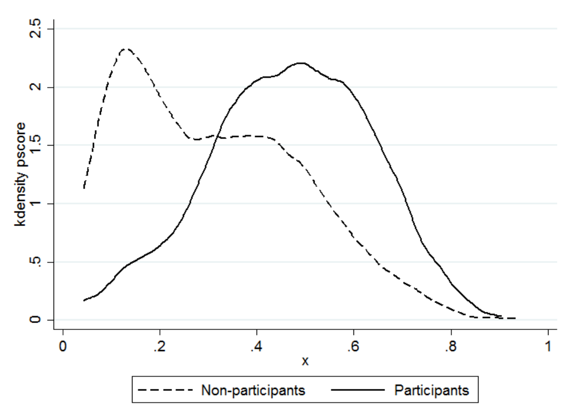


Figure B.3 Distribution P-score after trimming



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