Agricultural Transformation and Food and Nutrition Security: Does Farm Production Diversity (Still) Matter for Dietary Diversity among Ghanaian Farm Households?

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Abstract:

Africa has experienced rapid economic growth based on structural change in recent years. The growth acceleration in some countries, such as Ghana, was accompanied by substantial poverty reduction. Transformation of agriculture appears to have played a key role in this context. However, the implications of agricultural transformation for rural food and nutrition security in Africa are not well understood. This paper studies the case of Ghana—a country that may have outlined an Africa-typical path of growth-enhancing structural change. The analysis first describes patterns of agricultural transformation at the farm household level and then estimates the (causal) effects of farm production diversity and household income on household dietary diversity, using data from 2005-06 and 2012-13. The estimation results suggest that farm production diversity does still matter for dietary diversity across rural Ghana. However, the dietary diversity effect of farm production diversity greatly decreases with advancing agricultural transformation especially in the South, while the dietary diversity effect of household income remains fairly constant and is large. This implies that policies and programs promoting farm production diversification are likely to be increasingly less effective in improving food and nutrition security among farm households, particularly compared to those stimulating rural income growth.

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Abstract

Africa has experienced rapid economic growth based on structural change in recent years. The growth acceleration in some countries, such as Ghana, was accompanied by substantial poverty reduction. Transformation of agriculture appears to have played a key role in this context. However, the implications of agricultural transformation for rural food and nutrition security in Africa are not well understood. This paper studies the case of Ghana—a country that may have outlined an Africa-typical path of growth-enhancing structural change. The analysis first describes patterns of agricultural transformation at the farm household level and then estimates the (causal) effects of farm production diversity and household income on household dietary diversity, using data from 2005-06 and 2012-13. The estimation results suggest that farm production diversity does still matter for dietary diversity across rural Ghana. However, the dietary diversity effect of farm production diversity greatly decreases with advancing agricultural transformation especially in the South, while the dietary diversity effect of household income remains fairly constant and is large. This implies that policies and programs promoting farm production diversification are likely to be increasingly less effective in improving food and nutrition security among farm households, particularly compared to those stimulating rural income growth.

1. Introduction

Africa (south of the Sahara) experienced an acceleration of economic growth during the first one-and-a-half decades of the 21st century. Africa's recent economic growth has been associated with a substantive decline in the share of the labor force engaged in agriculture. This decline has been accompanied by a systematic increase in economywide labor productivity, as labor moved from low-productivity agriculture to higher-productivity services and manufacturing (Diao et al., 2017a). Rapid urbanization and high population growth rates in rural areas have fueled transformation of agriculture in addition. Urbanization and economic growth have provided farmers new market opportunities, while rising population pressure in rural areas have put traditional farming systems under mounting stress (Binswanger-Mkhize and Savastano, 2017). This has been associated with declining (or stagnant) per-capita farm sizes, shrinking fallow land areas, and decreasing fallow periods (Headey and Jayne, 2014; Jayne et al., 2014). Such changing farming and marketing conditions should foster agricultural commercialization and intensification of farming systems—at least theoretically (Pingali and Rosegrant, 1995).

At the farm household level, increasing commercialization is typically accompanied by specialization of production on few profitable crops that comes along with reduced farm production diversity and declining levels of household food self-sufficiency (Pingali and Rosegrant, 1995). Africa's farmers especially in remote areas, however, continue to face market failures that may not allow them to separate farm production decisions from household consumption decisions and hence rationalizes maintaining a high farm production diversity at (potentially high) costs of sacrificing profits for consumption risk mitigation (Morduch, 1995). To increase household incomes and reduce consumption risks, farm households tend to increasingly diversify their income sources into non-farm employment (Barrett et al., 2001).

The recent agricultural transformation is likely to have important implications for food and nutrition security in Africa. Food shortage and malnutrition remain a predominantly rural phenomenon across the region. Economic growth and agricultural transformation may offer an avenue to accelerate progress in improving food and nutrition security in rural areas through increasing farm income from growing (urban) food demand, increasing off-farm income from non-farm employment, and improved market access that enables rural consumers to smooth seasonal food shortages and to diversify their diets. Though, agricultural commercialization and farm production specialization especially into non-food cash crops may also come along with reduced diversity of food available to the farm household, if forgone cropping diversity for self-sufficiency is not compensated through market purchases. Poor dietary quality—lacking adequate amounts of various vegetables, fruits, pulses, and animal-source foods—is a leading cause for micronutrient malnutrition (Ramakrishnan, 2002; Ruel, 2001) and child stunting (Branca and Ferrari, 2002; Walker et al., 2007).

In the context of the recent agricultural transformation in Africa, household-level analysis on the effects of changing farming systems for rural food and nutrition security have experienced a revival. Examples include studies by Ritzema et al. (2017) using data from seven East and West African countries, Carletto et al. (2017) using data from Malawi, Tanzania, and Uganda; Sibhatu et al. (2015) using data from Ethiopia, Kenya, and Malawi and a Southeast Asian country (Indonesia); Hirvonen and Hoddinott (2017) and Michler and Josephson (2017) using data from Ethiopia; Romeo et al. (2016) using data from Kenya; and Jones et al. (2014) and Radchenko and Corral (2017) using data from Malawi.

This paper contributes to that strand of the literature. The analysis differs from that in previous studies in at least three important aspects: First, it uses data from two rounds of a (cross-sectional) household survey to analyze the relationship of farm production diversity and household dietary diversity at two different points in time and to explore potential changes in this relationship in consideration of agricultural transformation. Second, instead of relying on correlation (as most previous studies), it establishes statistical causality between farm production diversity and household dietary diversity. Third, it goes beyond estimating the average effect across all farm households and provides estimates for different parts of the study country to account for different stages of agricultural transformation and different agricultural production conditions and, additionally, for farm household groups with different farm sizes to allow for potential farm size-dependent differential effects.

This paper focuses on Ghana—a country that may have outlined an Africa-typical path of growth-enhancing structural change. Since the launch of the Economic Recovery Program in 1983, Ghana experienced rapid economic growth and urbanization (World Bank, 2017): Ghana's gross domestic product (GDP) per capita grew at an annual average rate of 2.8% between 1985 and 2015 and accelerated during the second half of this 30-year period, averaging an annual growth rate of 3.8% between 2000 and 2015. Along with that, the share of agriculture's value-added to GDP declined between 2000 and 2015 twice as fast as over the previous 15-year period. The proportion of the total population living in rural areas declined by around 0.7 percentage points per year between 1985 and 2015. For the first time, in 2010, less than half of all Ghanaians lived in rural areas, compared to two-third in 1985. In 2011, less than 40% of the total labor force were employed in agriculture, compared to more than half of the total labor force a decade earlier (GGDC, 2014). Nevertheless, agriculture remains the dominant source of livelihood across rural Ghana.

In Ghana, structural change positively contributed to economywide labor productivity growth in the 2000s (like in some other African countries) and already in the 1990s (unlike in most other African countries) (Diao et al., 2017a). Rapid economic growth in recent decades was accompanied by rapid poverty reduction in Ghana, as well as in Ethiopia, Rwanda, and Uganda, whereas—despite rapid economic growth—limited poverty reduction was achieved in Burkina Faso, Nigeria, Tanzania, and Zambia, for example (Arndt et al., 2016). Ghana also made substantial progress in improving food and nutrition security. It achieved the Millennium Development Goal targets of halving the proportion of people living in extreme poverty and the proportion of people suffering from hunger as one of the first countries in Africa and well ahead of the 2015 deadline (NDPC and UNDP, 2015). And, infant and young child malnutrition—especially child stunting—decreased substantially across the country in recent years (Ecker and van Asselt, 2017; IFPRI, 2015a). Agricultural transformation appears to have played a key role in Ghana's progress toward these development goals.

The analysis of this paper aims at first answering the question on whether—and by how much—farm production diversity affects household dietary diversity in South and North Ghana overall and among households with small, medium, and large farms. Then, it explores if the sizes of the hypothesized, overall effect in North and South Ghana decreased between 2005-06 and 2012-13, given agricultural transformation. The underlying hypothesis is that, with advancing agricultural transformation, farm production diversity becomes increasingly less important for household dietary diversity until farm households' food consumption is (largely) decoupled from on-farm production as in a well-integrated rural market economy with a highly commercialized agricultural sector. The results of the analysis may have important policy implications: They can provide general evidence on, for example, the expectable (relative) effectiveness of policies and programs that promote farm production diversification for improving rural food and nutrition security in Ghana or similar settings in other countries.

2. Methodology and Data

2.1 Empirical Strategy

The analysis econometrically estimates the effects of farm production diversity on household dietary diversity in Ghana in 2005-06 and 2012-13 and compares the average effect sizes, considering the recent agricultural transformation. Farm production diversity is the main independent variable of interest, because it is expected to decrease due to production specialization that typically comes along with agricultural commercialization and intensification of farming systems in developing countries (Pingali and Rosegrant, 1995). In subsistence-oriented farming systems, a diversified farm production, however, is important for attaining a diversified diet. This dependency tends to decrease with declining household food self-sufficiency levels and increasing market integration of rural areas (Pingali and Rosegrant, 1995).

Before turning to the econometric analysis, summary statistics of farm household variables indicative of agricultural transformation are presented. These indicators also enter the regression model as independent variables. The descriptive analysis employs *t*-tests (for unpaired data with unequal variances) to detect significant mean differences between the variables in the 2005-06 and 2012-13 data. Findings from the descriptive analysis helps interpreting the estimation results.

To estimate the causal effects of farm production diversity on household dietary diversity, the econometric analysis adopts a standard regression model: Because (subsistence-oriented) farmers may choose their cropping patterns considering their household dietary needs, an instrumental variables (IV) approach is used to deal with the potential endogeneity problem. Statistical tests of the validity of the chosen instruments are performed, and the robustness of the estimation results of the preferred model specification are checked against alternative specifications. The regression model is estimated for all farm households of the study samples and, additionally, for three subsamples of households with small, medium, and large farms. The rationale for this disaggregation is that the implied relationship between farm production diversity and dietary diversity may be different subject to the land area available for cultivation, which should be explored in the analysis. It is easily conceivable that, especially under subsistence conditions, the hypothesized effect is different for farmers who must feed their families from a small land area than for farmers who have more land under cultivation.

The econometric analysis needs to overcome data limitations and take regional differences across Ghana into account. The applied data are taken from the fifth and sixth round of the Ghana Living Standards Survey, conducted in 2005-06 and 2012-13, respectively (GLSS5, GLSS6; GSS, 2006, 2013). The GLSS is a cross-sectional household survey that is designed to provide nationally and regionally representative indicators. The GLSS5 and GLSS6 used identical sampling methods and employed very similar—but not fully identical—questionnaires in each round. The only difference between the GLSS5 and GLSS6 questionnaires that matters for this analysis is the length of the recall periods in the food consumption modules, which are used to construct dietary diversity indicators. In the GLSS5, food consumption was surveyed using a three-day recall that was repeated ten times consecutively to cover a period of 30 days. The GLSS6 used a five-day recall that was repeated six times consecutively. Because households tend to consume a larger number of different foods or food groups over a longer period of time, the GLSS5 and GLSS6 data cannot be pooled for estimation, and comparisons of the estimated dietary diversity effects across survey rounds are inaccurate without standardization of the estimated effect sizes.

Separate estimations are performed for the GLSS5 and GLSS6, using identical specifications of the regression model. The model is also estimated separately for South and North Ghana for two main reasons: First, agricultural production conditions and hence traditional food consumption patterns are substantially different. There is a long and a short rainy and dry season per year in the South, while there is only one rainy and one dry season in the North. Roots and tubers (and partly plantains) are traditional staple crops in the tropical South, whereas cereals are the dominant staple crops in the North. Livestock production—particularly cattle husbandry—is concentrated in the North. Accordingly, there are different agroecological zones (AEZ). The GLSS5 differentiates three AEZs: the Coastal and Forest AEZs in the southern part and the Savannah AEZ in the northern part. Second, there are distinct south-north gaps in economic development, population density, degree of urbanization, and level of rural infrastructure endowment (Diao et al., 2017b). Agricultural transformation therefore can be expected to be more advanced in the South than the North. For the analysis, the GLSS5 and GLSS6 datasets are split along the borders of the AEZs that largely coincide with the borders of Ghana's administrative regions. The South is defined as the part of the country that comprises the Coastal and Forest AEZs, and the North as the part that is constituted of the Savannah AEZ.

To accurately compare the sizes of the average dietary diversity effects estimated from the GLSS5 and GLSS6 data, the estimates are expressed in standard deviation (SD) changes of the dietary diversity variable. These changes are calculated per 1SD-change in the farm production diversity variable and per 1SD-change in the household income variable. Comparison of the dietary diversity effect sizes of farm production diversity and household income provides information on the relative importance of the effects.

2.2 Estimation Model

The IV regression model has the following estimation equations:

(1) $\boldsymbol{\lambda} = c_1 + \alpha \boldsymbol{X} + \gamma_1 Z + \delta_1 \rho + \varepsilon_1$

(2) $\boldsymbol{\mu} = c_2 + \beta \hat{\boldsymbol{\lambda}} + \gamma_2 Z + \delta_2 \rho + \varepsilon_2$

In the first-stage estimation equation (Eq. 1), $\boldsymbol{\lambda}$ is a farm production diversity indicator, which predicted values enter the second-stage estimation equation (Eq. 2). In Eq. 2, $\boldsymbol{\mu}$ denotes a dietary diversity indicator. In the first equation, $\boldsymbol{X}$ is a vector of exogenous variables that is highly correlated with $\boldsymbol{\lambda}$ but not independently correlated with $\boldsymbol{\mu}$. The exogenous variables are the average length of the plant growing period and the average soil organic carbon content per administrative district. Both variables are indicators of the local agricultural production potential.

The vector Z includes a set of farm household characteristics as controls. The continuous variables included in Z are total household expenditure per capita (as proxy indicator of household income), food self-sufficiency level (as indicator of the degree of subsistence farming), off-farm working hours per capita (as indicator of participation in non-farm employment), farm size per capita (as indicator of land pressure for supplying family members with food), and household size (as indicator of economies of scale). The vector Z includes several binary variables that capture the presence of cash crop production, livestock, and poultry on the farm and the location of the farm household by AEZ (in the South). The vector Z also controls for standard characteristics of the household head (as the main decision maker), including sex, age, and attained formal education level. The variable ρ denotes the district population density (as proxy indicator of the degree of urbanization and local market integration).

The constant terms are c_1 and c_2. The coefficients to be estimated are α, β, γ_1, γ_2, δ_1, and δ_2; ε_1 and ε_2 are residual error terms that are randomly distributed across households. The IV regression model is implemented using two-stage least squares (2SLS) estimators. Standard errors are estimated to be robust to both arbitrary heteroskedasticity and arbitrary intra-cluster correlation, where household clusters are given by the surveys' enumeration areas.

2.3 Samples and Variables

The sample populations of this study comprise farm households that are defined as households that live in rural areas and cultivate agricultural land of at least 0.5 acres and not more than 50 acres. The total sample of farm households in the GLSS5 dataset includes 3,994 households that equal 46.3% of the rural households who completed the survey. The total sample of farm households in the GLSS6 dataset includes 7,223 households that equal 43.2% of the rural households who completed the survey. Table 1 presents the number of farm household observations in the South and North samples and their subsamples of small, medium, and large farms. To obtain the subsamples, the South and North samples were subdivided into tertiles based on the cultivated land area per household.

Table 1. Farm size ranges and number of observations in the South and North samples

		GLSS5 (2005-06)			GLSS6 (2012-13)	
		South	North		South	North
Total	Farm size (acres)	0.5 – 50.0	0.5 – 50.0		0.5 – 50.0	0.5 – 50.0
	Households	*2,369*	*1,625*		*3,447*	*3,776*
Small	Farm size (acres)	0.5 – 2.5	0.5 – 3.0		0.5 – 3.0	0.5 – 4.0
	Households	*837*	*647*		*1,219*	*1,446*
Medium	Farm size (acres)	2.6 – 6.0	3.1 – 6.0		3.1 – 6.5	4.1 – 8.0
	Households	*849*	*514*		*1,185*	*1,188*
Large	Farm size (acres)	6.1 – 50.0	6.1 – 50.0		6.6 – 50.0	8.1 – 50.0
	Households	*745*	*579*		*1,159*	*1,218*

Source: Own calculation, based on GLSS5 and GLSS6 data (GSS 2006, 2013).

In a developing country context, dietary diversity is a common proxy indicator of dietary quality, which is key to food and nutrition security. Dietary quality refers to the nutritional adequacy of a diet that meets individuals' requirements for calories and essential nutrients. Validation studies show that dietary diversity indicators are consistently and strongly associated with household calorie consumption (Ruel, 2003) and adequate micronutrient content and/or density of children's and women's diet (Ruel et al., 2013). Recent studies also confirm a positive association between dietary diversity indicators and the nutritional status of children and women as measured by anthropometry (Ruel et al., 2013). Moreover, the rationale for using dietary diversity as proxy indicator for food and nutrition security is well-founded in economic theories of demand, as well as psychological theories such as Maslow's hierarchy of needs (Headey and Ecker, 2013). The theories suggest that households will only diversify into higher-value, micronutrient-rich foods (such as animal-source foods, vegetables, and fruits) when they have satisfied their calorie needs.

The dietary diversity indicator in the preferred specifications of the regression model is the number of different food groups that the household consumed over the survey recall period. This dietary diversity indicator includes 12 food groups, which correspond to the food groups of the

Household Dietary Diversity Score (HDDS) (Swindale and Bilinsky, 2006).[1] As a robustness check, this indicator is replaced by the number of different foods consumed over the recall period; 50 foods are considered. Both dietary diversity indicators are averaged over all (completed) recall repetitions of the GLSS food consumption modules.

The regressions are run for two farm production diversity indicators. In the preferred model specifications, the first indicator is the simple count of different cultivated crop groups, and the second indicator is Simpson's diversity index (Simpson, 1949) calculated based on these crop groups. The crop groups were defined to be consistent with the food groups of the food group-based dietary diversity indicator; eight crop groups are considered.[2] The Simpson diversity index is calculated as:

$$(3) \qquad \lambda = 1 - \sum_{i=1}^{R} s_i^2 ,$$

where R is the number of cultivated crop groups, and s is the share of the farm land area cultivated with crop group i. Hence, R is equivalent to the first farm production diversity indicator, which measures the richness of crop cultivation. In addition to that, the Simpson diversity index accounts for the evenness of the farm land allocation to different crop groups. The Simpson diversity index takes values between zero and one, with zero indicating monoculture and one indicating infinite diversity. The number of cultivated crop groups and the

[1] The HDDS food groups are cereals; starchy roots and tubers and plantains; vegetables; fruits; meat and poultry; fish and seafood; eggs; pulses, nuts, and seeds; milk and dairy products; edible oils and fats; sugars; spices and condiments (Swindale and Billinski, 2006).

[2] The crop groups of the farm production diversity indicators are cereals; starchy roots and tubers and plantains; vegetables; fruits; legumes and nut trees; oil crops; spices and others; and non-food cash and fiber crops (including cocoa and sugarcane).

Simpson diversity index have been used in similar studies (e.g., Hirvonen and Hoddinott, 2017; Sibhatu et al., 2015; and Jones et al., 2014; Snapp and Fisher, 2015; respectively). As a robustness check, the crop group-based indicators were replaced with farm production diversity indicators constructed based on different (food) crops and using the same methodology; 31 food crops and one aggregate for non-food cash and fiber crops are considered. The reference period of all farm production diversity indicators is the past 12 months.

The data underlying the exogenous variables of the regression model were provided by the HarvestChoice project (IFPRI, 2015b). The average length of the plant growing period per year and the soil organic carbon content (measured at 15-30 cm depth) available at the spatial raster level were interpolated to each obtain one observation per district. The used vector map includes 110 districts—the number of districts at the time of the 2000 Population and Housing Census (PHC) that also underlies the GLSS5 sampling.

The variables of farm household characteristics are derived from various GLSS modules. Total household expenditure per capita is calculated as the sum of reported food and non-food expenditures and the estimated market values of the consumed quantities of own-produced foods, divided by household size. The level of food-sufficiency is the share of home consumption on total food consumption in monetary value terms. Household off-farm working hours per capita is calculated as the sum of reported working hours in (paid) non-farm employment of all household members aged seven years and older over the past seven days divided by the number of these household members. Farm size per capita is the total land area cultivated by a household divided by household size. Household size is defined as the number of persons who usually live and eat together in the household.

District population density is calculated using district population data from the 2000 PHC and 2010 PHC and the land areas of the (old) 110 districts. The district population density in 2000 is matched to the GLSS5 data, and the district population density in 2010 is matched to the GLSS6 data.

All continuous, non-fractional variables enter the regressions in logarithms. Hence, the coefficient estimates of continuous variables can be interpreted as elasticities.

3. Results

3.1 Patterns of Agricultural Transformation

Table 2 reveals distinct patterns of agricultural transformation at the farm household level between 2005-06 and 2012-13 that were considerably different in Ghana's South and North in several aspects. Over the seven-year period, the average farm production diversity declined in the South (at least if measured by the number of cultivated crop groups), whereas it increased in the North. Nevertheless, the farm production diversity remained to be higher in the South than the North, which may largely be explained by more favorable agricultural production conditions in the South.

In 2005-06 and 2012-13, the average farm size per household was larger in the North than the South, but, on a per-capita basis, it was smaller in the North because of much large average household size (5.6 persons, compared to 4.5 persons in the South, in 2012-13). Over the seven-year period, the average farm size both per household and per capita increased in the North, whereas it did not change significantly in the South. This result firstly indicates that the average land pressure among farm households has been higher in the North than the South and secondly suggests that farm land expansion in the North came along with growing farm household sizes. This association is supported by correlation coefficients: The correlation between farm size (per household) and household size in the North was larger in 2012-13 (0.330) than in 2005-06 (0.275) and larger than in the South, where the correlations were similar in both years (0.196 and 0.207, respectively).

Table 2. Summary statistics and mean difference tests for agricultural transformation variables

	South						North					
	2005-06		2012-13		Percent	Sign. level	2005-06		2012-13		Percent	Sign. level
	Mean	SD	Mean	SD	change at	of mean	Mean	SD	Mean	SD	change at	of mean
Farm production diversity												
Number of cultivated crop groups	2.16	0.95	2.10	0.83	-2.9	***	2.03	1.01	2.15	0.96	6.0	***
Simpson diversity index for cultivated crop groups	0.41	0.23	0.40	0.23	-1.5		0.35	0.27	0.38	0.24	8.8	***
Farm size (acre)												
per household	6.42	7.45	6.47	6.45	0.8		7.07	7.71	7.85	7.27	11.1	***
per capita	2.10	3.60	2.01	2.96	-4.2		1.53	2.09	1.73	2.02	13.1	***
Proportion of farm households with more than …												
3 acres	0.55	0.50	0.59	0.49	6.0	**	0.64	0.48	0.74	0.44	16.4	***
6 acres	0.31	0.46	0.40	0.34	8.5	**	0.33	0.47	0.43	0.50	31.4	***
Household expenditure per capita (GHC/month)	115	90	173	217	50.9	***	58	57	102	103	74.8	***
Food self-sufficiency level	0.40	0.21	0.38	0.23	-5.1	***	0.59	0.25	0.53	0.24	-10.4	***
Off-farm working hours per capita (hours/week)	23.6	16.0	25.6	16.2	8.1	***	25.0	16.5	26.4	16.8	5.7	***

Source: Own estimation, based on GLSS5 and GLSS6 data (GSS 2006, 2013).

Note: GHC = Ghana Cedi.

***, ** Per a *t*-test for unpaired data with unequal variance, the mean difference is statistically significant at the 1% and 5% level, respectively.

The proportion of farm households with more than three acres and, even more so, the proportion of farm households with more than six acres increased in the South and the North between 2005-06 and 2012-13—but at much high rates in the North than the South. This result confirms the overall trend of greater land concentration among medium-scale farmers in Ghana found by Jayne et al. (2016) and further suggests that the national trend is mainly driven by the land expansion of farm households in the North.

Household income—as proxied by total household expenditure—substantially increased on a per-capita basis among farm households in the South and the North between 2005-06 and 2012-13. However, the precise expenditure estimates for 2005-06 and the large average changes to the 2012-13 level reported in Table 2 should be interpreted cautiously, as the results may be driven to some extent by the applied (official) price deflator that does not account for likely differences in subnational price movements.

The average food self-sufficiency level of farm households declined in the South and the North between 2005-06 and 2012-13. It declined faster in the North than the South—though, from a much higher level in the North. Nevertheless, subsistence-oriented farming remains common, especially in the North: On average, 53% of total food consumption came from own production among farm households in 2012-13, compared to 38% among farm households in the South.

Consistent with the general trend of rising income diversification in rural areas across most of Africa in recent decades (Davis et al., 2010; Haggblade et al., 2010), non-farm employment to complement farm income become more important in the South and the North between 2005-06 and 2012-13. The average per-capita number of weekly working hours spent in (paid) jobs outside the family farm increased faster in the South than the North.

Altogether, these patterns confirm that agricultural transformation has been more advanced in the South than the North. They also show that the average changes in all considered indicators of agricultural transformation at the farm household level are in the (expected) same direction and were much larger in the North than the South—with the clear exception of farm production diversity. The found decline in the average number of cultivated crop groups in the South clearly indicates progressing farm specialization on fewer crop groups. The found tendency toward farm production diversification in the North may be related to increasing average farm sizes, where the land expansion allows farmers to produce additional crop groups. Together with the high level of food self-sufficiency, it suggests that market failures which prevent farmers to separate farm production decisions from household consumption decisions have been prevailing in the North. In sum, agricultural transformation appears to be at a very early stage in the North.

3.2 Estimation Results

Tables 3-6 present the second-stage estimation results of the preferred model specifications for the main variables of interest.[3] The coefficient estimates indicate a positive and statistically significant relationship between farm production diversity and dietary diversity across all farm households in Ghana's South and North in both 2005-06 and 2012-13. Thus, farming diversification is generally associated with improved household dietary quality among Ghanaian farmers, keeping all other factors constant. This result holds for farm production diversity as measured by the number of cultivated crop groups as well as the Simpson diversity index for cultivated crop groups. The coefficient estimates suggest that, in 2005-06, a 1%-change in the

[3] The complete estimation results of the preferred model specification can be obtained upon request.

richness of crop cultivation on the farm was associated with a change in dietary diversity by 0.36% in the South and by 0.43% in the North. When considering the evenness of land allocation in crop cultivation in addition to its richness, the respective changes in dietary diversity were 0.65% in the South and 0.96% in the North. The estimation results from the 2012-13 data confirm this pattern of smaller dietary diversity effects in the South than the North and larger dietary diversity effects when considering the evenness of crop cultivation in addition to its richness than the latter one alone. In 2012-13, a 1%-change in the number of cultivated crop groups was associated with a dietary diversity change by 0.15% in the South and 0.65% in the North, and a 1%-change in the Simpson diversity index was associated with a dietary diversity change by 0.29% in the South.

For the subsamples of small, medium, and large farms, the estimated relationship between farm production diversity and dietary diversity is consistently positive. However, the respective coefficient estimates are often statistically insignificant at the 10% level, which may be partly due to limited numbers of observations per cluster and large variations in the estimation variables. Among all subsample estimations, the estimations for medium farmers in the South in 2005-06 and large farmers in the North in 2012-13 yield coefficient estimates with the highest significance levels for both farm production diversity indicators. Overall, the subsample estimations do not provide strong, consistent evidence for farm size-dependent differential effects of farm production diversity on household dietary diversity.

Table 3. Second-stage estimation results of the preferred model specification for the 2005-06 South sample

Dep. var.: Number of consumed food groups (log)	All farms				Small farms				Medium farms				Large farms			
	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.
Number of cultivated crop groups (log)	0.360	**			0.422	*			0.381	**			0.260			
Simpson diversity index for cultivated crop groups			0.653	***			0.683	*			0.688	**			0.719	*
Household expenditure per capita (GHC/month; log)	0.272	***	0.272	***	0.293	***	0.292	***	0.266	***	0.266	***	0.250	***	0.243	***
Food self-sufficiency level	-0.063		-0.050		-0.019		0.003		-0.096		-0.085		-0.066		-0.080	
Off-farm working hours per capita (hours/week; log)	0.008		0.006		0.002		0.001		0.022		0.023		-0.004		-0.010	
Farm size per capita (sq.rod; log)	0.219	***	0.233	***	0.267	***	0.270	***	0.240	***	0.257	***	0.188	***	0.192	***
Observations (households)	2,369		2,369		839		839		793		793		737		737	
Clusters (EAs)	202		202		184		184		184		184		169		169	
RMSE	0.247		0.249		0.259		0.262		0.238		0.243		0.236		0.247	
Underidentification test [a]	20.09	***	22.56	***	9.91	***	8.82	**	16.66	***	18.84	***	7.91	**	10.19	***
Weak identification test [b]	10.06	**	10.44	**	3.48		3.03		11.02	**	13.15	***	3.91		5.54	
Test of overidentifying restrictions [c]	2.958	*	2.503		2.286		2.265		0.942		0.796		1.800		1.051	

Source: Own estimation, based on GLSS5 data (GSS 2006).

Note: GHC = Ghana Cedi; 1 acre = 160 square rods; EA = enumeration area; RMSE = root-mean-square error.

***, **, * Coefficient is statistically significant at the 1%, 5%, and 10% level, respectively. Standard errors are robust to heteroskedasticity and intra-cluster correlation.

[a] Kleibergen-Paap rank LM-statistic (Baum et al., 2010; Kleibergen and Paap, 2006): ***, **, * Test statistic rejects the null hypothesis of underidentification at the 1%, 5%, and 10% level, respectively.

[b] Kleibergen-Paap rank Wald F-statistic (Baum et al., 2010; Kleibergen and Paap, 2006): ***, **, * Test statistic rejects the null hypothesis of weak identification at, respectively, the 15%, 20%, and 25% level based on the critical values provided by Stock and Yogo (2005).

[c] Hansen J-statistic (Baum et al., 2010): ***, **, * Test statistic rejects the null hypothesis of zero correlation between the instruments and the error term at the 1%, 5%, and 10% level, respectively.

Table 4. Second-stage estimation results of the preferred model specification for the 2005-06 North sample

Dep. var.: Number of consumed food groups (log)	All farms				Small farms				Medium farms				Large farms			
	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.
Number of cultivated crop groups (log)	0.433	*			0.614	**			0.501				0.178			
Simpson diversity index for cultivated crop groups			0.960	*			1.219	*			0.973				0.380	
Household expenditure per capita (GHC/month; log)	0.254	***	0.241	***	0.259	***	0.240	***	0.297	***	0.286	***	0.248	***	0.247	***
Food self-sufficiency level	0.079		0.037		0.102		0.077		0.144		0.115		-0.030		-0.047	
Off-farm working hours per capita (hours/week; log)	-0.005		-0.006		0.011		0.017		-0.033		-0.030		0.014		0.011	
Farm size per capita (sq.rod; log)	0.128	*	0.136	*	0.262	***	0.261	***	0.136		0.162	*	0.142	*	0.156	**
Observations (households)	1,625		1,625		591		591		500		500		534		534	
Clusters (EAs)	127		127		112		112		110		110		101		101	
RMSE	0.308		0.338		0.328		0.381		0.340		0.353		0.248		0.248	
Underidentification test [a]	8.89	**	6.00	**	5.32	*	3.52		9.08	**	7.22	**	9.44	***	8.49	**
Weak identification test [b]	5.89		3.70		3.70		2.26		5.81		4.36		4.14		4.38	
Test of overidentifying restrictions [c]	1.195		1.203		0.137		0.021		0.018		0.184		1.736		1.986	

Source: Own estimation, based on GLSS5 data (GSS 2006).

Note: See note to Table 3.

Table 5. Second-stage estimation results of the preferred model specification for the 2012-13 South sample

Dep. var.: Number of consumed food groups (log)	All farms				Small farms				Medium farms				Large farms			
	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.
Number of cultivated crop groups (log)	0.151	*			0.069				0.097				0.133			
Simpson diversity index for cultivated crop groups			0.285	*			0.112				0.210				0.420	
Household expenditure per capita (GHC/month; log)	0.256	***	0.258	***	0.263	***	0.264	***	0.283	***	0.283	***	0.228	***	0.229	***
Food self-sufficiency level	-0.185	***	-0.185	***	-0.117	***	-0.115	***	-0.260	***	-0.261	***	-0.162	**	-0.198	***
Off-farm working hours per capita (hours/week; log)	-0.003		-0.003		0.002		0.002		-0.015		-0.017		0.006		0.004	
Farm size per capita (sq.rod; log)	0.248	***	0.255	***	0.284	***	0.284	***	0.244	***	0.243	***	0.194	***	0.212	***
Observations (households)	3,447		3,447		1,422		1,422		896		896		1,129		1,129	
Clusters (EAs)	336		336		314		314		288		288		266		266	
RMSE	0.231		0.233		0.229		0.230		0.237		0.238		0.215		0.221	
Underidentification test [a]	33.40	***	36.67	***	28.90	***	29.54	***	24.81	***	22.53	***	15.73	***	12.92	***
Weak identification test [b]	16.82	***	19.00	***	13.98	***	14.90	***	11.84	***	11.13	**	12.04	***	9.22	**
Test of overidentifying restrictions [c]	0.613		0.293		0.481		0.467		1.312		1.169		4.631	**	3.038	*

Source: Own estimation, based on GLSS6 data (GSS 2013).

Note: See note to Table 3.

Table 6. Second-stage estimation results of the preferred model specification for the 2012-13 North sample

Dep. var.: Number of consumed food groups (log)	All farms				Small farms				Medium farms				Large farms			
	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.	Coef.	Sign.
Number of cultivated crop groups (log)	0.654	**			0.266				0.765	*			0.415	***		
Simpson diversity index for cultivated crop groups			1.038				0.304				2.130				1.421	***
Household expenditure per capita (GHC/month; log)	0.252	***	0.268	***	0.262	***	0.261	***	0.255	***	0.248	***	0.237	***	0.224	***
Food self-sufficiency level	-0.230	***	-0.218	***	-0.127	**	-0.115	**	-0.236	***	-0.226	**	-0.226	***	-0.346	***
Off-farm working hours per capita (hours/week; log)	-0.015		-0.014		-0.003		-0.001		-0.042		-0.064		0.007		-0.002	
Farm size per capita (sq.rod; log)	0.126		0.184	***	0.230	***	0.247	***	-0.002		-0.092		0.195	***	0.227	***
Observations (households)	3,776		3,776		1,428		1,428		1,177		1,177		1,171		1,171	
Clusters (EAs)	294		294		264		264		274		274		236		236	
RMSE	0.330		0.314		0.251		0.245		0.363		0.497		0.254		0.336	
Underidentification test [a]	6.94	**	3.68		5.07	*	9.28	***	4.47		1.63		21.90	***	15.98	***
Weak identification test [b]	3.46		1.98		2.75		5.56		2.25		0.84		18.39	***	9.84	**
Test of overidentifying restrictions [c]	1.201		4.516	**	1.379		1.432		0.707		1.143		0.899		0.508	

Source: Own estimation, based on GLSS6 data (GSS 2013).

Note: See note to Table 3.

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The estimated relationship between household income and dietary diversity is positive and highly statistically significant for all samples and subsamples. Thus, increasing household income—independent of its source—was universally associated with improved dietary quality among all farm household groups. The income elasticities of all sample and subsample estimations are similar. A 1%-change in household income was associated with a change in dietary diversity by 0.24–0.30% in 2005-06 and 0.22–0.28% in 2012-13, depending on the farm household group and the part of the country. The subsample estimations indicate a slight—but consistent—tendency: The income effect was larger for households with small or medium farms than it was for households with large farms. The estimation results provide no indication that participation in non-farm employment by itself affects dietary diversity among Ghanaian farm households. The respective coefficient estimates are statistically insignificant and close to zero in all sample and subsample estimations.

The relationship between households' food self-sufficiency level and dietary diversity is statistically significant in all sample and subsample estimations for 2012-13 but in no estimation for 2005-06 (Tables 3-6). The negative coefficient estimates for the 2012-13 (sub)sample estimations imply that, more recently, a high dependence of household food consumption on own-production was associated with a low diversity of the consumed diet, or conversely, that households who sourced large shares of their food consumption from market purchases tended to have a more diversified diet. This result is consistent with findings on the importance of market integration for improving dietary quality and nutrition in other African countries that experience rapid structural change such as Ethiopia (Hirvonen and Hoddinott, 2017; Hirvonen et al., 2017).

Farm size per capita is statistically significantly and positively related to dietary diversity across almost all samples and subsamples. This association suggests that farm households that must feed many household members from a given area of cultivated land tend to have a diet that is less rich in diversity than households with the same farm size but fewer members. It implies that land pressure adversely affects dietary diversity beyond the effect resulting from adjustments in farm production diversity—possibly through yield losses from soil degradation.

3.3 Validity Tests and Robustness Checks

The hypothesis of this paper rests on the assumption that there is a causal relationship between farm production diversity and dietary diversity. Establishing statistical causality requires identifying valid instruments of the endogenous regressor (that is, farm production diversity). Identification test statistics (reported in Tables 3-6) provide supportive evidence for this validity assumption in most estimations of the preferred model specifications and especially in the estimations for Ghana's South.

In all estimations for the South samples and subsamples, the Kleibergen-Paap rank LM-statistic rejects—and, mostly, strongly rejects (at the 1% significance level)—the null hypothesis of model underidentification. The Kleibergen-Paap rank Wald F-statistic also rejects the null hypothesis of weak identification at the common confidence level in the estimations for all farm households in the South in 2005-06 and 2012-13, the estimations for the South subsamples of medium-farm households in 2005-06, and all South subsample estimations in 2012-13. The latter, however, show statistically insignificant coefficient estimates for the dietary diversity effect of farm production diversity.

The Kleibergen-Paap rank LM-statistic rejects the null hypothesis of model underidentification in most estimations for the North samples and subsamples. Exceptions include the estimations for the sample of all farm households in 2012-13 and the subsample of small-farm households in 2005-06 that have the Simpson diversity index as endogenous regressor and both estimations for the subsample of medium-farm households in 2012-13 (Tables 5 and 6). For the estimations that pass the underidentification test, the Kleibergen-Paap rank Wald F-statistic rejects the null hypothesis of weak identification at the common confidence level only for the subsamples of large-farm households in 2012-13. Thus, except for the estimations for this subsample, the chosen instruments perform poorly in establishing causality between farm production diversity and dietary diversity in all estimations for the North. A possible explanation may be that, compared to the South, there are other agroecological factors in the North that essentially influence farm production diversity especially on small and medium farms. Such potential factors may include rainfall variability and drought occurrence, which (wealthier) larger farmers may be able to better cope with, such as because of access to irrigation water (Wossen et al., 2014).

Of all estimations of the preferred model specifications that pass the underidentification test (and the weak identification test), only three estimations do not pass the test of overidentifying restrictions. They are the estimation for the South sample of all farm households in 2005-06 that has the number of cultivated crop croups as endogenous variable and both estimations for the South subsample of large-farm households in 2012-13. For these estimations, the Hansen J-statistic rejects the null hypothesis of zero correlation between the instruments and the error term at least at the 10% significance level, which casts doubt on the validity of the chosen instruments.

Performed robustness checks confirm that the found relationship between farm production diversity and dietary diversity is not sensitive to the specification of the indicators used in the preferred model specifications. The estimations that have the number of consumed foods—instead of the number of consumed food groups—as dependent variable and the estimations that have the number of cultivated crops—instead of the number of cultivated crop groups—or the Simpson diversity index for cultivated crops—instead of the Simpson diversity index for cultivated crop groups—as endogenous variable all show a positive relationship between farm production diversity and dietary diversity.[4] The significance levels of the coefficient estimates and the test statistics partly differ between the preferred and alternative specifications of the regression model, which, however, does not alter the main findings.

Overall, the estimations for the South samples of all farm households in 2005-06 and 2012-13, the South subsamples of medium-farm households in 2005-06, and the North subsamples for large farms in 2012-13 yield the strongest results.

3.4 Comparison of Effect Sizes

Table 7 presents standardized effect sizes for the dietary diversity effects of farm production diversity and household income across all farm households in the South and North. The table reports the SD-change in dietary diversity per 1SD-change in the farm production diversity or household income indicators. This standardization permits comparisons of the dietary diversity effect sizes in 2005-06 and 2012-13 and relative to an equivalent change in the determining variable. The effect sizes are reported, if the respective coefficient estimate is statistically significant at least at the 10% level. For the farm production diversity indicators, the effect sizes

[4] The estimation results and test statistics of these alternative regression model specifications can be obtained upon request.

have gray font, if the respective estimation did not pass the tests of underidentification, weak identification, and overidentifying restrictions, and therefore are interpreted more cautiously.

Table 7. SD-change in dietary diversity per 1SD-change in farm production diversity and household income

Dep. var.: Number of consumed food groups (log)	South				North			
	2005-06		2012-13		2005-06		2012-13	
Number of cultivated crop groups (log)	0.56		0.21		0.66		0.97	
Simpson diversity index for cultivated crop groups		0.55		0.22		0.79		
Household expenditure per capita (GHC/month; log)	0.60	0.60	0.60	0.60	0.61	0.58	0.59	0.63

Source: Own estimation, based on GLSS6 data (GSS 2013).

Comparing the effect sizes reveal three important findings: First, the relevance of farm production diversity for dietary diversity in the South greatly decreased between 2005-06 and 2012-13; the estimated effect sizes dropped by more than half. This finding provides supportive evidence for the hypothesis that, with advancing agricultural transformation, farm production diversity becomes increasingly less important for dietary diversity among farm households—at least in Ghana's South. The estimated effect sizes for the North indicate a tendency toward an increase in the relevance of farm production diversity for dietary diversity between 2005-06 and 2012-13.

Second, in the South, the dietary diversity effect of farm production diversity was smaller than the dietary diversity effect of household income in both 2005-06 and 2012-13. It suggests that farm production diversity has been less important for dietary diversity than household income among farmers in the South. In contrast, the dietary diversity effect of farm production diversity seems to have been larger than the dietary diversity effect of household income among farmers in the North. This finding implies that, at a very early stage of agricultural transformation—like in Ghana's North, farm production diversity matters more for dietary diversity than household real income, while, at an advanced stage, it is the other way around.

Third, the dietary diversity effect of household income was similarly large in 2005-06 and 2012-13, especially in the South. It suggests that the dietary diversity effect of household income remained fairly constant during Ghana's agricultural transformation thus far and that it has been fairly constant across the different parts of the country and different farm sizes, as noted above.

4. Conclusions

Ghana may have outlined an Africa-typical path of economic growth-enhancing structural change. Like several other African countries, Ghana experienced rapid economic growth based on structural change in recent years. However, structural change positively contributed to economywide labor productivity growth in Ghana earlier than in many other African countries. Ghana also managed to utilize the recent acceleration of economic growth for poverty reduction—like only some other countries in Africa—and for improvements in food and nutrition security. Transformation of agriculture appears to have played a key role in this context.

Yet, the effects of agricultural transformation on food and nutrition security at the farm household level and on household dietary diversity in particular are not well understood. Detailed understanding of these effects is essential for assessing the potential contribution of the advancing agricultural transformation to improving food security and reducing malnutrition and for designing and implementing supportive agricultural policies and complementary social protection programs in Ghana and other African countries that face rapid structural change. This paper intended to narrow the gap in the respective literature by providing empirical evidence from rural Ghana.

The descriptive analysis of this paper documents patterns of agricultural transformation at the farm household level and shows that agricultural transformation that has been much more advanced in the South than the North. In both parts of the country, the level of food self-sufficiency among farm households declined between 2005-06 and 2012-13, the proportions of households with medium and large farms increased, and non-farm employment as complementary income source became more important. Differences in the patterns of agricultural transformation between the South and the North are likely due to different agricultural production conditions and demographic factors as well as their different stages in the process of structural change. In the North, the average farm size both per household and per capita increased between 2005-06 and 2012-13, whereas it did not change significantly in the South. Household farm sizes have been larger in the North than the South, but, because of much larger household sizes, farm households in the North have had less cultivated land per capita, on average. This, in addition to less favorable production conditions, points to a high pressure on household farm land in the North. The observed land expansion of farm households in the North may therefore be driven by the farmers' need to keep up with supplying food for their growing family sizes to some extent. On average, farm production diversity declined in the South but increased in the North between 2005-06 and 2012-13, while farm production remained to be more diversified in the South. Hence, there has been a clear tendency toward farm specialization in the South. The observed farm production diversification together with still high household food self-sufficiency in the North suggest that market failure which prevent farm households to separate production decisions from consumption decisions have been prevailing in this part of the country. Thus, land acquisition and, along with it, production diversification appears to be the dominant strategy to increase household dietary diversity among farmers in the North. In sum, agricultural transformation is advancing in the North, but it is still at a very early stage.

The econometric analysis shows that farm production diversity does still matter for dietary diversity among farm households across Ghana. However, from 2005-06 to 2012-13, the size of the dietary diversity effect of farm production diversity decreased substantially in the South, where agricultural transformation and rural market integration have been much more advanced than in the North. Correspondingly, the dietary diversity effect in the North have been larger than in the South. Unlike in the North, the dietary diversity response to a change in farm production diversity was smaller than the dietary diversity response to an equivalent change in household income in the South in 2005-06 and, even more so, in 2012-13. While the relevance of farm production diversity for dietary diversity decreased, the dietary diversity effect of household income remained fairly constant over the seven-year observation period—especially in the South. These findings together suggest that, with advancing agricultural transformation, farm production diversity becomes increasingly less important for household dietary diversity and particularly relative to household income. They confirm the main hypothesis of this paper—at least for Ghana's South. The size of the dietary diversity effect of household income was relatively similar for households with small, medium, and large farms in 2005-06 and 2012-13, with a slight tendency of larger effects for small- and medium-farm households.

The findings have several important policy implications: Because the relevance of farm production diversity for dietary diversity among farm households greatly decreases with advancing agricultural transformation, policies and (large-scale) programs which promote farm production diversification for improving household dietary quality through home consumption are becoming less effective over time—at least in Ghana. In contrast, rural economic growth and agricultural transformation policies that increase farm household incomes (from farming activities or non-farm employment) and foster rural market integration are likely to be more effective in improving household dietary quality and reducing food and nutrition insecurity more generally. This holds particularly for households with small and medium farm sizes. To leverage agricultural growth-enhancing transformation for improving rural food and nutrition security in lagging regions such as in Ghana's North, infrastructural investments, regulatory reforms, and perhaps economic stimulus programs are necessary to increase market penetration and help farmers to commercialize and specialize without compromising their households' dietary quality.

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