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Effects on Sector Orientation and Factor Intensity

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The role of agricultural productivity in non-farm activities in Nigeria: Effects on sector orientation and factor intensity

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Abstract

The role of agricultural productivity on non-farm economies in developing countries remains widely debated in the literature. A knowledge gap exists particularly regarding the heterogeneity among non-farm activities, in terms of sectoral orientations, factor intensities, and returns to factors, and the effects of agricultural productivity on these aspects. Using nationally representative household data from Nigeria, this study shows that higher agricultural productivity leads to generally greater capital and labor uses for non-farm activities by the households. This effect is particularly stronger for non-farm activities that are agriculture-oriented, as compared to those that are not agriculture-oriented. Furthermore, higher agricultural productivity raises returns to capital and labor for agriculture-oriented non-farm activities, potentially enhancing the contribution of non-farm economies to overall economic and income growth. By also increasing the labor use for both farming and non-farm activities, higher agricultural productivity is also found to increase overall rural employment. In obtaining these results, we use an agroclimatic similarity index to instrument household-level total factor productivity in agriculture.

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Keywords: agricultural productivity, non-farm economies, agriculture-related non-farm activities, agroclimatic similarity, Box-Cox double-hurdle, Nigeria

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1 Introduction

The linkage between agricultural productivity and the growth of non-farm (NF) economies¹ in developing countries is still widely debated in the literature. Agricultural development has traditionally been considered an important source of capital that is needed for the growth of the industrial sector and the overall economy (Schultz 1953; Lewis 1954; Johnston & Mellor 1961). Studies continue to show the roles of agricultural sector on overall economic development around the world (McArthur & McCord 2017; Gollin et al. 2018). On the other hand, higher agricultural productivity may be negatively associated with the growth of the NF-sector, if the NF-sector essentially competes with the farm sector for production factors (Matsuyama 1992; Foster & Rosenzweig 2004). Negative linkages (or the lack of a positive linkage) between various measures of agricultural productivity and NF-activities are also reported in recent studies, including Amare & Shiferaw (2017) and Djido & Shiferaw (2018). Investigating this linkage remains important for many developing countries in Africa. For example, such an understanding may offer insights into why in some African countries the NF economy has been growing without a significant agricultural transformation (McMillan et al. 2016).

In the present study, we fill this knowledge gap by examining the role of agricultural productivity in NF-activities in Nigeria, using a nationally representative panel household survey data with detailed information on agricultural production behaviors, and the types of NF-activities engaged by farm household members. Specifically, we offer empirical insights into three dimensions of the linkage between agricultural productivity and household participation into NF-activities.

First, we investigate the effects of agricultural productivity on households' factor use (capital and labor) in NF-activities. Higher agricultural productivity may induce overall growth of, and investments into, NF-activities if a rise in food productivity reduces the "food problem" and releases labor to the modern sector (Schultz 1953; Matsuyama 1992; Gollin et al. 2014). Where the NF-sector is more productive than the farming sector, but liquidity constraints disable the entry into the former, high agricultural productivity provides increased agricultural incomes which in turn provide capital to overcome liquidity constraints (Haggblade et al. 1989). However, under different assumptions, these effects are reversed, particularly in open economies relative to closed economies, where more agents specialize in agricultural production to earn incomes and to purchase non-agricultural products and services (Matsuyama 1992). Where factors including capital are mobile enough, liquidity constraints become mitigated, and lower wages as the results of lower agricultural productivity actually attract more NF-sector (Foster & Rosenzweig 2004). Where the unemployment rate is high, higher agricultural productivity could increase labor engagements in both sectors, simply reducing unemployment.

Second, we test if higher agricultural productivity induces shifts to NF-activities that are directly linked with agriculture (ANF hereafter), away from another non-agriculture-related NF (NNF hereafter). Haggblade et al. (1989) describe five linkages through which agricultural productivity relates to the NF-sector (capital flows, labor flows, production or backward linkages, forward linkages, and consumption linkages), many of which appear more closely associated with ANF-activities. In particular, the production linkages (increased demand for agricultural inputs and related services like mechanization) and forward linkages (processing of agricultural

¹In this paper, we define "non-farm" economies as "all economic activity other than crop and livestock production, encompassing services, construction, mining, commerce and manufacturing" including "agroindustrial activities which store, process and market agricultural commodities" (Haggblade et al. 1989, p.1174). The recent literature also largely follows this definition, which is also consistent with the classification used in our primary data.

commodities) they describe are largely agricultural. Similarly, labor mobility remains relatively low in developing countries (Jayachandran 2006; Jacoby 2016), despite the growing migration. If ANF-activities are more concentrated spatially around production areas, higher agricultural productivity may also induce local labor to engage more in ANF-activities. Furthermore, if there are differential effects on ANF- and NNF-activities, and these types of NF-activities differ in terms of capital and labor intensity, higher agricultural productivity may also have differential effects on capital and labor uses in NF by the households.

Third, we test if higher agricultural productivity is associated with higher returns to factors (capital and labor) in NF, and whether they differ between ANF and NNF. Mitigating liquidity constraints for NF can be one contribution of agricultural productivity-NF linkage. However, if returns in NF are also affected by agricultural productivity, the linkages are likely to be more fundamental and long-lasting.

Nigeria is a particularly interesting case to investigate these issues. The NF-sector has increased its share in both economy and employment in Nigeria recently. Between 2014-2016, the NF-sector in Nigeria accounted for 79% of gross domestic product (GDP) (58% by the service sector, and 21% by the industry sector) (World Bank 2018) and employed approximately 50% of the workforce (Groningen Growth and Development Center 2018). Despite such an economic transformation, close to 70 percent of the population still live under the poverty line of 1.25 dollar per day in purchasing power parity (World Bank 2018), and in 2015, approximately 30 percent of the active labor force (22.4 million out of 76.9 million) are either unemployed or underemployed (Adesugba & Mavrotas 2016). Agricultural productivity has remained low in Nigeria albeit with recent catchup (Benin 2016; Nin Pratt & Yu 2010). The recent growth of the NF-sector in Nigeria might have been led by the allocation of resources (labor, capital) to the NF-sector, induced by the low returns to these resources in the agricultural sector. In other words, the NF-sector may be growing simply because the opportunities in the farm sector are so low. In such a case, the contribution of NF-sector growth to overall economic growth is limited. This is consistent with the fact that, despite being a middle-income country, the poverty rate in Nigeria is still quite high.

Our study contributes to the literature in two important ways. First, our study uses total factor productivity (TFP) in agriculture, which has not been used widely in the literature when investigating the linkages between agricultural productivity and NF at the household levels. Our study uses household level TFP estimated through the production function utilizing the panel nature of the data, and a novel instrumental variable that measures the agroclimatic similarity between the locations where households are located and where plant breeding activities are conducted. Most technical change in agriculture has involved improvements in biological processes (Timmer 1988). Plant breeding activities and resultant varietal technologies often contribute significantly to agricultural TFP (Evenson & Gollin 2003; Walker & Alwang 2015), and spillover potential is often higher between agroclimatically similar locations (Griliches 1991; Evenson & Westphal 1995; Alston 2002; Takeshima & Nasir 2017). TFP is more suitable than, for example, yield or partial labor productivity, in countries such as Nigeria, where mixed-cropping is still prevalent, but the use of inputs other than land and labor (such as chemical fertilizer, animal tractions) has also been rising, relative to labor, although use of these other inputs remains at low levels (Takeshima et al. 2013; Takeshima & Nkonya 2014). Second, few studies have investigated the heterogeneous effects of agricultural productivity on NF. Our study sheds more light on the heterogeneity within the NF-sector in terms of sectoral orientations, as well as factor intensities. Using nationally representative data from Nigeria, our results show that higher agricultural productivity leads to increased capital injection and generally greater labor use in the

NF-sector. In addition, the effect on participation in and labor use for NF-activities is particularly stronger for ANF, as compared to NNF, while the effect on capital investments for NF is stronger for NNF. Furthermore, higher agricultural productivity raises the returns to capital and labor for ANF, which potentially enhances the contributions of NF to overall economic and income growth.

The rest of this paper is structured as follows. Section 2 briefly discusses conceptual theories. Section 3 describes the empirical methods we employed in the analysis. Section 4 discusses the descriptive statistics. Section 5 presents the empirical results, while section 6 concludes the paper.

2 Empirical methods

2.1 Data

The primary data used in our analysis are from the Living Standards Measurement Study – Integrated Survey on Agriculture (LSMS-ISA) collected jointly by the National Bureau of Statistics of Nigeria and the World Bank over three waves (2010/11, 2012/13, 2015/16). Each wave of the LSMS-ISA consists of the post-planting survey which primarily collects data on agricultural inputs used from the beginning of the year, which typically covers the planting period of the rainy season, as well as the data on dry season output. The post-harvesting survey collects data on the rainy season outputs. Both surveys also collected detailed information about the engagements of households and their members in different types of off-farm income earning activities including those in the NF-sectors that are both agriculture-related and non-agriculture-related.

Each wave of LSMS-ISA covers a panel of approximately 5,000 households that were nationally representative in Wave 1 and tracked in Waves 2 and 3. Among these samples, our analysis focuses on approximately 8,500 observations of farm households from the three Waves combined, who reported agricultural production values, as well as all the relevant information needed for our analyses, such as GPS-measured farm size. Samples who moved to other unknown enumeration areas (EAs) during three rounds of surveys were also dropped because our analyses rely on the information about agroclimatic conditions extracted based on the locations of each EA. Furthermore, Waves 2 and 3 report detailed information that allows us to disaggregate NF-activities into ANF- and NNF-activities. After excluding households with missing information, approximately 5,500 farm households in Waves 2 and 3 are used for some of the in-depth analyses.

In addition, various spatial agroclimatic data are merged with the LSMS-ISA data using the coordinates of EAs. Slope of the land is available in the LSMS-ISA data set. The data on historical rainfall as well as its anomaly and wind speed at 10 meters above ground is obtained from the Climatic Research Unit of the University of East Anglia (Climatic Research Unit 2017). Solar radiation is obtained from NASA (2018). Terrain ruggedness is calculated using GTOPO30 (U.S. Geological Survey 1996) and the formula used by Riley et al. (1999). Soil-related data are taken from 1km resolution soils mapping data (International Soil Reference and Information Centre (ISRIC) 2013; Hengl et al. 2014).

2.2 Specifications

Our empirical approach consists of the following procedures. First, a production function is estimated through fixed-effects-panel Ordinary Least Square (OLS) in Cobb-Douglas form as:

$$\ln Y_{it} = \alpha^Y + \sum_K \beta_K \ln(K_{it}) + \beta_{Irr} Irr_{it} + \beta_{Rain} Rain_{it} + \delta_i + \varepsilon_{it} \quad (1)$$

where Y_{it} is the output, K_{it} is a set of inputs, Irr_{it} is a dummy variable indicating the use of irrigation, $Rain_{it}$ is 12 months rainfall, for survey year t for household i . α^Y is the intercept, while δ_i is the unobserved household fixed effects, which create household level variations in agricultural TFP as $\alpha + \delta_i$.

We then estimate TFP by instrumenting the estimated value of household fixed effects δ_i (c_i) by exogenous variables, including *agroclimatic similarity* with the plant breeding locations (A_i). A_i measures the similarity of overall agroclimatic conditions between the areas where farm household i is located, and locations where plant breeding is conducted. Appendix A describes in detail the construction of A_i . A_i has been found an important determinant of agricultural TFP in Nigeria because such similarity highly determines the spill-over potential of improved varieties developed by the public sector (Takeshima & Nasir 2017) and has been used in the studies on other countries (Takeshima & Liu 2018). In particular, in Nigeria, 6 locations (Badeggi, Ibadan, Kano, Maiduguri, Umudike, and Zaria) have accounted for 90 percent of varieties developed and released in Nigeria (Takeshima & Nasir 2017), and the agroclimatic similarity with these plant breeding locations is likely to be a major determinant of agricultural TFP.

Specifically, we estimate:

$$c_i = \alpha^c + \gamma_A A_i + \sum_X \gamma_X \bar{X}_i + u_i \quad (2)$$

where \bar{X}_i is the time-average of exogenous variables X_{it} , while α^c , γ_X and u_i are parameters and error terms. Predicted values from (2), \tilde{c}_i , is then used as an indicator of TFP of the household i . Using predicted value \tilde{c}_i , instead of c_i , addresses the potential endogeneity between NF-activities-related indicators and agricultural productivity, which arises because household NF-activities can also affect household agricultural productivity.

Effects of agricultural productivity on NF-activities

We then estimate:

$$N_{it} = \alpha^N + \delta_C \tilde{c}_i + \sum_X \delta_X X_{it} + v_{it} \quad (3)$$

where N_{it} is various NF-activities-related indicators of our interests, including participation in NF-activities, capital, and labor uses, as well as returns to capital and labor, for both ANF- and NNF-activities. Parameters δ_C , which is our primary interest, measures the effect of agricultural productivity on NF-activities-related indicators.

Identification issues

Estimations (1) through (3) rely on the identification assumption that, agroclimatic similarity A_i affect N_{it} only through the effects on agricultural productivity \tilde{c}_i , and does not directly affect N_{it} . This is a reasonable assumption because of various factors. First, it is important to note that, as is described in the next sub-section, X_{it} includes all the agroclimatic variables, so that the effects of agroclimatic conditions on N_{it} are controlled for. A_i differs from these agroclimatic variables in that A_i contains further exogenous variations due to the relative locations of a household i and plant breeding locations, which are functions of not only the agroclimatic conditions of i but those of plant breeding locations.

Second, despite the significant effects on agricultural TFP, the government support for plant breeding activities has accounted for a very small share of its overall GDP in Nigeria.² Therefore, A_i is unlikely to have any direct effects on N_{it} aside from its effects on agricultural TFP. These conditions provide the ground that A_i satisfies the exclusion restriction in (3).

Standard errors

Equations (1) through (3) are estimated in multiple steps, which involves the estimation of \hat{c}_i and \tilde{c}_i and using them as explanatory variables. Standard errors in (2) and (3) are, therefore, calculated through 200 paired bootstrap (Efron 1979; Freedman 1981). Paired bootstrap has been commonly used for similar multi-step estimations (e.g., Takeshima & Winter-Nelson 2012).

Robustness check

As is described more in detail in the results section, we also try different specifications for (3) as robustness checks. These include using different agricultural productivity measurements in place of \tilde{c}_i , addressing unobserved time-invariant fixed effects that potentially remain in v_{it} , and addressing the truncated nature of some indicators of N_{it} .

2.3 Variables

Agricultural production and inputs uses

Agricultural production and inputs uses, used for estimating the household TFP, are obtained from the agricultural module of LSMS-ISA data. Specifically, agricultural production is measured as the real total production value aggregated across all crops and livestock products produced within the 12 months. Since total harvest in rural Africa is sometimes more accurately captured in consumption (Deininger et al. 2013), we combined the quantities sold (which are often more accurately reported than the total harvest) and the reported quantities of consumption sourced from household production. Input variables are constructed from agricultural modules as well.

Sectoral orientation of NF-activities

Waves 2 and 3 of LSMS-ISA data report in detail the type of NF-activities engaged in by the households. Using their descriptions, we classify them into ANF- and NNF-activities.³

Earnings, returns to labor, and capital in NF enterprises

Earnings in NF enterprises are constructed by using the revenues and costs during one month prior to the interview and multiplying them by 12 to reach annual equivalent figures. Costs include the salary payment for hired workers (some of whom are family members). Returns to labor and returns to capital are then calculated by dividing the residual earnings by the number of unpaid

²Beintema et al. (2017) estimate that Nigeria spends only 0.2% of agricultural GDP on agricultural research and development, which is approximately 0.04% of total GDP.

³We define agriculture-related NF as follows: First, any activities under “Manufacture of food” (coded as Enterprise 10 in LSMS-ISA) are all classified as agricultural. For other enterprises, those containing the following terms are classified as agricultural: (a) “food,” “food stuff,” “agric,” “farm,” “butchers,” “restaurant,” “local brewery”; (b) names of agricultural inputs (fertilizer, insecticides, pesticides, tractors, etc.) (c) Names of locally prepared food (Akara, Akamu (Pap), Akpu, Awara, Burkutu, Chin, Daddawa, Ekuru, Egusi, Elubo, Fufu, Fura, Garri, Karago, Kuli, Kuka, Kunu, Masa, Moimoi, Nono, Ogbono, Ogiri, Ogooro, Okpei, Pito, Suya, Tuwo, Ugba, Wara, Zobo); and (d) Names of crops, Livestock products, Animals (cassava, cattle, hide and skin, etc.). By these definitions, “Agriculture-related” NF include any activities that are associated with these (marketing, processing, etc.).

family members involved (who are the managers of the enterprise), as well as the value of the capital stock for the enterprises.

Explanatory variables

Variables X_{it} consist of variables S and/or D , which affect the supply and/or demand for household NF-activities. In particular, S is associated with factors affecting costs of capital, labor, and other materials used as inputs, while D is associated with factors affecting returns from NF-activities. Furthermore, neither S nor D should be affected by A_i , as described earlier.

In our analysis, many variables are associated with S , D , or both.⁴ Agroecological variables (rainfall, wind, solar radiation, slope, terrain ruggedness, soil characteristics), aside from the effects on agricultural productivity, generally affect the costs of NF-activities. For example, wind and solar radiation may affect electricity generation through renewable energy sources and sand characteristics may affect manufacturing of bricks, while topography affects transportation costs, among other effects. Soil characteristics are also highly correlated with hydrological conditions. Combined with rainfall, they may affect the availability of water, which is used in various NF-activities including manufacturing. Monthly rainfall anomaly is also included as it may affect both the demand for certain NF-activities (trading of agricultural inputs, agricultural mechanization services), as well as the supply of certain NF-activities (food processing, etc.). Specifically, we calculate the percentile of monthly rainfall according to historical distributions over the past 30 years, obtain two principal components of the percentiles, and use these as rainfall anomaly indicators.

General household demographics include such variables as age, gender, working-age members, dependency ratios, and general labor endowments of the households, as well as demand for incomes derived from household NF-activities.

Household human capital is proxied by average years of formal education completed by working-age household members. Higher human capital is associated with both S (skills, business management, etc.) and D (general demand for manufactured goods and services, as well as processed food due to high opportunity costs for cooking, etc.).

Household wealth is associated with both S (for example, to finance NF capital as well as to bear business-related risks) and D (greater ability to consume manufactured goods and services rather than to smooth consumption). Values of household and total household income levels play these roles. Owning farm land (obtained through outright purchase) may also indicate its usability as collateral to obtain credit to start NF-activities (association with S), while relatively stronger tenure may also induce greater demand for services from ANF-sector (association with D). An indicator of local wealth level, proxied by the sample average of total household incomes within the EAs⁵ used in LSMS-ISA data, which the household resides in, may be also associated with S (e.g. more informal credit available for NF-activities), and D (e.g. greater demand for locally produced goods and services with positive income elasticity of demand).

Access to various institutions and infrastructure is associated with S and D , generally through reduced transactions costs. Distance to the nearest town with a population of 20k or more

⁴Because we estimate reduced form equations, not structural models of supply and demand of NF-activities, the distinction between S and D , as well as channels, is not so important and need not be rigid (although we still try to loosely associate each variable to S and/or D and specific channels, so that stories become clearer).

⁵LSMS-ISA data used 500 EAs as the sampling framework in wave 1, from which 10 households were randomly selected for the interviews.

captures the access to basic institutions that are often present in the towns of minimum scale. Distance to the administrative center captures the access to institutions that are available in State capital, including the headquarters of the Agricultural Development Project (ADP) which provide various agricultural-sector related services. Distance to the nearest urban centers with a population of 500k or more captures the access to more selected imported goods, including raw imported materials for manufacturing machines or their spare parts.⁶ We also specifically include distance to Lagos and Kano, which are major manufacturing centers in Nigeria (Bloch et al. 2015), and Nnewi in Anambra state, which hosts one of the largest automobile clusters in Nigeria as well as the whole of West Africa (Brautigam 1997; Abiola 2008). These cities may be characterized more as “production cities”, which may have a different industrial structure from other urban centers that may be characterized as consumption cities (Gollin et al. 2016), and thus have differential associations with *S* and *D*. Access to formal sector finance is proxied by whether there is a bank within the community where the household resides, and the distance to the nearest bank.

Aside from the distance to towns of varied sizes and administrative centers, local population density is also included to proxy the local-level agglomeration-effects that attract external capital investments (including those for NF-activities). Social capital is proxied by the presence of household members working for the government, since it may facilitate access to various pieces of information about government programs, and thus decisions on NF-activities.

We also include estimated rates of subsidies applied by the state government, provided by Banful et al. (2010).⁷ The fertilizer subsidies have often been found to crowd out the commercial fertilizer supply business (Takeshima and Nkonya 2014), thus potentially negatively affecting the returns to certain ANF-activities like inputs trading.

Other various relevant shocks were also captured, which may be associated with both *S* and *D*. Positive shocks are proxied by whether the community where the household resides received new sources of electricity (on-grid or off-grid), and the EA sample average value of safety nets received, both in the past 12 months. Negative shocks are proxied by the incidence of human epidemic diseases in the community in the past 12 months (likely including Ebola, which spread widely in the West Africa region in 2013–2016).

While our focus is not on separately identifying *S* and *D*, some factors may be relatively more closely related to *D* or *S*, but not both. The incidence and expenditure intensity of funerals in the local area may particularly be associated with *D*, affecting the demand for certain NF-activities including food manufacturing, since it is common for funeral expenses in an African community to be associated with such large spending including on food consumption (Case et al. 2014).

All the specifications also include dummy variables identifying the waves of the survey, and Nigeria’s six geopolitical zones, to account for year- and region-specific factors. In addition, a dummy variable for the states of Adamawa, Borno and Yobe is included, as these states have seen excessive disruptions in various economic activities due to Boko-Haram’s terrorist activities during the period covered in the study.

⁶The list of urban areas with more than 1 million of estimated population in 2018 is obtained from <http://www.demographia.com/db-worldua.pdf>. These cities include, Lagos, Onitsha, Kano, Ibadan, Abuja, Uyo, Port Harcourt, Nsukka, Benin City, Aba, Kaduna (over 1 million), Ilorin, Jos, Ikorodu, Owerri, Maiduguri, Warri, Enugu, Zaria, Osogbo, Akure, Sokoto, Lokoja, Bauchi, Abeokuta, Ogbomosho (over 0.5 million).

⁷In Nigeria, chemical fertilizer has been historically subsidized by states at varying subsidy rates, in addition to subsidies by the federal government (Takeshima & Nkonya 2014). The state subsidies have become politically entrenched, where significant changes in subsidy rates often face opposition. Many states had kept their fertilizer subsidy programs during the period covered in Wave 2. Anecdotal evidence suggests that they have remained in place even after the introduction of the Agricultural Transformation Agenda in 2011, toward the period covered in Wave 3.

3 Descriptive statistics

Table 1 through Table 3 summarize the descriptive statistics of explanatory variables, dependent variables (factor uses in NF-activities of different types), and agricultural production practices (which are used to estimate agricultural productivity).

Table 1 suggests that most sample households are of low-income (based on total expenditure per capita), with members completing relatively low levels of formal education, and male-headed. Few of them also have secure land titles. There is also, however, considerable heterogeneity in their characteristics, as indicated by the standard deviations.

Table 1. Descriptive statistics (N = 5575 of farm households in Waves 2 and 3)^a

Variables	Mean	Standard deviation
Agroclimatic similarity index (standardized to [0, 1])	0.75	0.10
12 months rainfall (historical, mm)	1,369.63	613.43
Wind at 10 m height (meter per second)	2.53	0.57
Solar radiation (kwh/m ² , annual average)	5.33	0.53
Slope (%)	2.73	2.74
Terrain ruggedness (index)	26.20	39.21
Soil cation exchange rate (index)	8.24	3.02
Soil acidity (pH)	5.93	0.61
Soil component: Silt (%)	16.32	7.63
Soil component: Clay (%)	17.44	5.31
Soil component: Organic contents (g/kg of soil)	12.26	6.41
Soil component: Bulk density (metric ton/m ³)	1.33	0.10
Rainfall anomaly (Principal Component 1)	-0.60	2.53
Rainfall anomaly (Principal Component 2)	-0.31	1.53
Household size (working age member)	2.41	1.48
Household dependency ratio	3.72	2.38
Female household head (yes = 1)	0.14	0.35
Age of household head (year)	52.79	14.57
Average education of working-age members (year)	3.18	3.81
Own farm land (yes = 1)	0.18	0.39
Household asset (value)	1,013.90	6,167.37
Household expenditure per capita (12 months, value)	147.25	237.07
EA sample average expenditure per capita (12 months, value)	303.93	130.84
EA incidence of funeral (proportion of sample households)	0.06	0.12
EA average expenses on funeral (value)	18.56	74.66
State fertilizer subsidy rate (reference rate in 2010, %)	20.20	14.95
New electricity in the community (yes = 1)	0.03	0.17
Population density (person / km ²)	447.69	1230.29
Distance to the nearest 20k town (km)	25.37	17.91
Distance to the administrative center (km)	74.70	53.63
Whether having banks within the community (yes = 1)	0.34	0.47
Travel time to the nearest bank (hours)	0.11	0.29
Euclidean Distance to the nearest urban center (Geographical minutes)	1.49	1.29
Euclidean Distance to Lagos (Geographical minutes)	5.73	2.38
Euclidean Distance to Kano (Geographical minutes)	4.24	2.03
Euclidean Distance to Nnewi (Geographical minutes)	3.78	2.53
Conflict states (=1 if Adamawa, Borno, Yobe states)	0.09	0.29
Human epidemic disease in the community (=1 if yes)	0.02	0.13
Household member employed in the government (=1 if yes)	0.07	0.26
Value of safety net received (EA sample average, value)	0.42	3.31

Source: Authors.

Note: EA = enumeration area; g = grams; kg = kilograms; km = kilometers; km² = square kilometers; kwh/m² = kilowatt hour per square meter; m³ = cubic meter; mm = millimeter.

^aAll “value” are in kg of staple crops evaluated at local price.

Table 2 summarizes the capital investments, and other financial resources uses, as well as household labor uses in NF enterprises and household labor uses in NF-sector wage-employment. About 70 percent of these farm households engage in NF-activities. While NNF-activities are more common, more than 1/3 of them also engage in ANF-activities. The intensity of resource uses is somewhat higher among NNF-activities, which are particularly more fixed-capital intensive, while ANF-activities are relatively more labor- and variable-capital intensive.

Table 2. Descriptive statistics: household level factor use in NF-activities (N = 5575)^a

Variables	Mean	Standard deviations
<i>NF-enterprise capital (value)</i>		
All	371.41	1,727.91
ANF	0.43	4.14
NNF	370.98	1,726.4
<i>Non-labor expenses in NF-enterprises over 12 months (value) – including purchase of raw materials</i>		
All	1,157.08	5,485.65
ANF	334.06	2,007.99
NNF	823.01	5,059.54
<i>Non-labor expenses in NF-enterprises over 12 months (value) – excluding purchase of raw materials</i>		
All	301.63	2039.85
ANF	79.24	423.17
NNF	222.39	1979.57
<i>Family members engaged in NF-enterprises (person-enterprise count)</i>		
All	1.19	1.60
ANF	0.65	1.14
NNF	0.69	1.45
<i>Wage employment in the NF-sector (person-days in 12 months)</i>		
All	170.55	278.40
ANF	48.55	139.53
NNF	122.00	218.56
<i>Whether at least one household members engage in NF-activities (yes = 1)</i>		
All	0.72	0.45
ANF	0.37	0.48
NNF	0.60	0.49

Source: Authors.

Note: NF = non-farm. ANF = agriculture-related NF. NNF = non-agriculture-related NF.

^aAll “value” are in kg of staple crops evaluated at local price.

Table 3 summarizes the agricultural production characteristics. Table 3 suggests that our sample consists of highly heterogeneous agricultural households, particularly in terms of land cultivated and agricultural capital owned (as shown in somewhat high standard deviations relative to the mean). To make our analysis inclusive, we kept the fraction of the sample that is made up of large farmers in our analysis. However, we also repeated the analysis excluding farms cultivating more than 10 ha, and/or having agricultural capital that is worth more than 10 metric tons of cereals, which accounted for about 5 percent of the sample. We found that our results are stable following this approach.

Table 3. Descriptive statistics on agricultural production

Variables	Mean	Standard deviations
Agricultural output (value) ^a	73,189.89	273,823.10
Labor use (person day)	418.65	422.04
Land (ha)	1.35	5.60
Animal traction use (number of heads times days)	2.87	8.18
Other expenses on all non-labor inputs, services used, including chemical fertilizer, agrochemicals, or mechanization services (value) ^a	195.75	447.73
Agricultural capital (value) ^a	67.68	3,281.45
Using irrigation (yes = 1)	0.028	0.166
12 months rainfall (observed in surveyed years) (mm)	911.23	378.37

Source: Authors.

Note: ha = hectares; mm = millimeters.

^aAll “value” are in kg of staple crops (rice and gari, which is grated cassava) evaluated at their average local prices.

Table 4 shows the sample distributions of different types of NF-activities and NF-enterprises, constructed using the methods described above. Table 4 shows the distributions of ANF-enterprises and NNF-enterprises. Some NF-enterprises are more clearly agriculture-oriented, while other NF-enterprises are mostly non-agriculture-oriented. Interestingly, however, ANF- and NNF- activities are found in a variety of enterprises.

Table 4. Proportions of ANF-enterprises of each type (Number of observations)

NF-Enterprise type	Wave 3			Wave 2		
	Nona Agri gricul tural	Agri cultu ral	Total	Nona Agri gricul tural	Agri cultu ral	Total
Crop and Animal Production, Hunting and Related Service Activities	11	22	33	13	26	39
Forestry and Logging	8	1	9	7	2	9
Fishing and Aquaculture	8	18	26	8	21	29
Mining of Coal and Lignite	3	0	3	3	1	4
Extraction of Crude Petroleum and Natural Gas	1	0	1	1	4	5
Mining of Metal Ores	1	1	2	3	1	4
Other Mining and Quarrying	13	0	13	9	1	10
Mining Support Service Activities	4	0	4	3	0	3
Manufacture of Food Products	85	313	398	90	313	403
Manufacture of Beverages	13	40	53	12	35	47
Manufacture of Tobacco Products	1	1	2	1	1	2
Manufacture of Textiles	32	3	35	23	2	25
Manufacture of Wearing Apparel	326	2	328	314	1	315
Manufacture of Leather and Related Products	16	2	18	15	2	17
Manufacture of Wood and of Products of Wood and Cork, Except Furniture;	44	2	46	46	1	47
Manufacture of Paper and Paper Products	0	0	0	1	0	1
Printing and Reproduction of Recorded Media	3	0	3	1	0	1
Manufacture of Coke and Refined Petroleum Products	0	0	0	0	0	0
Manufacture of Chemicals and Chemical Products	5	0	5	5	0	5
Manufacture of Basic Pharmaceutical Products and Pharmaceutical Preparations	2	0	2	2	0	2
Manufacture of Rubber and Plastics Products	0	0	0	0	0	0
Manufacture of Other Non-Metallic Mineral Products	0	0	0	0	0	0
Manufacture of Basic Metals	23	0	23	25	0	25
Manufacture of Fabricated Metal Products, Except Machinery and Equipment	35	0	35	27	0	27
Manufacture of Computer, Electronic and Optical Products	5	0	5	4	0	4
Manufacture of Electrical Equipment	0	0	0	0	0	0
Manufacture of Machinery and Equipment	1	1	2	1	0	1
Manufacture of Motor Vehicles, Trailers and Semi-Trailers	1	0	1	0	0	0
Manufacture of Other Transport Equipment	2	0	2	2	0	2

NF-Enterprise type	Wave 3			Wave 2		
	Nona gricul tural	Agri ral	Total	Nona gricul tural	Agri ral	Total
Manufacture of Furniture	86	4	90	81	4	85
Other Manufacturing	82	22	104	66	18	84
Repair and Installation of Machinery and Equipment	35	1	36	33	0	33
Electricity, Gas, Steam and Air Conditioning Supply	3	0	3	1	0	1
Water Collection, Treatment and Supply	8	2	10	5	2	7
Sewerage	0	0	0	1	0	1
Waste Collection, Treatment and Disposal Activities	0	0	0	0	0	0
Remediation Activities and Other Waste Management Services	1	0	1	1	0	1
Construction of Buildings	159	2	161	145	3	148
Civil Engineering	12	4	16	12	4	16
Specialized Construction Activities	51	1	52	49	1	50
Wholesale and Retail Trade and Repair of Motor Vehicles and Motorcycles	74	7	81	72	10	82
Wholesale Trade, Except of Motor Vehicles and Motorcycles	18	7	25	16	10	26
Retail Trade, Except of Motor Vehicles and Motorcycles	2140	1076	3216	2000	1022	3022
Land Transport and Transport Via Pipelines	398	4	402	367	3	370
Water Transport	1	0	1	1	0	1
Air Transport	0	1	1	0	0	0
Warehousing and Support Activities for Transportation	5	1	6	4	1	5
Postal and Courier Activities	0	0	0	0	0	0
Accommodation	5	0	5	4	0	4
Food and Beverage Service Activities	43	177	220	47	170	217
Publishing Activities	3	0	3	2	0	2
Motion Picture, Video and Television Program Production, Sound Recording and Music Publishing Activities	5	1	6	4	1	5
Programming and Broadcasting Activities	1	0	1	0	0	0
Telecommunications	3	0	3	4	0	4
Computer Programming, Consultancy and Related Activities	4	0	4	4	0	4
Information Service Activities	2	0	2	3	0	3
Financial Service Activities, Except Insurance and Pension Funding	0	0	0	0	0	0
Insurance, Reinsurance and Pension Funding, Except Compulsory Social Security	0	0	0	0	0	0
Activities Auxiliary to Financial Service and Insurance Activities	1	0	1	1	0	1
Real Estate Activities	10	0	10	8	0	8
Legal and Accounting Activities	1	0	1	1	0	1
Activities of Head Offices; Management Consultancy Activities	4	0	4	4	0	4
Architectural and Engineering Activities; Technical Testing and Analysis	7	0	7	7	0	7
Scientific Research and Development	0	0	0	0	0	0
Advertising and Market Research	1	0	1	1	0	1
Other Professional, Scientific and Technical Activities	39	2	41	42	3	45
Veterinary Activities	0	0	0	0	0	0
Rental and Leasing Activities	6	0	6	5	0	5
Employment Activities	0	0	0	0	0	0
Travel Agency, Tour Operator, Reservation Service and Related Activities	5	0	5	4	0	4
Security and Investigation Activities	2	1	3	2	1	3
Services to Buildings and Landscape Activities	11	0	11	10	0	10
Office Administrative, Office Support and Other Business Support Activities	2	1	3	2	1	3
Public Administration and Defense; Compulsory Social Security	2	0	2	1	0	1
Education	9	0	9	9	0	9
Human Health Activities	28	6	34	29	4	33
Residential Care Activities	0	0	0	0	0	0
Social Work Activities Without Accommodation	8	0	8	8	0	8
Creative, Arts and Entertainment Activities	16	0	16	16	0	16
Libraries, Archives, Museums and Other Cultural Activities	3	0	3	2	0	2
Gambling and Betting Activities	3	0	3	5	0	5
Sports Activities and Amusement and Recreation Activities	1	0	1	1	0	1
Activities of Membership Organizations	1	0	1	1	0	1
Repair of Computers and Personal and Household Goods	29	1	30	26	1	27

NF-Enterprise type	Wave 3			Wave 2		
	Nona gricul tural	Agri ral	Total	Nona gricul tural	Agri ral	Total
Other Personal Service Activities	451	86	537	427	81	508
Activities of Households as Employers of Domestic Personnel	4	1	5	6	0	6
Undifferentiated Goods- and Services-Producing Activities of Private Households for Own Use	3	1	4	3	1	4
Activities of Extraterritorial Organizations and Bodies	2	0	2	2	0	2

Source: Authors' calculations based on Living Standards Measurement Study – Integrated Survey on Agriculture (LSMS-ISA) data.

Note: NF = non-farm. ANF = agriculture-related NF.

4 Empirical results

We first report the results of the relations between agricultural productivity, and participations and factor uses in NF-activities. We then report the results for the effects on returns in NF-activities.

As was described above, our measure of household agricultural productivity is calculated as the predicted TFP. Appendix B shows the estimated coefficients of production function (Table 10), and instrumenting function (Table 11). The estimated coefficients in Table 10 are factor shares in the production, which are all positive and significant, as expected. In addition, the irrigation dummy is positive and significant as expected.

Table 11 suggests that time-invariant household fixed effects, which reflect the household-level variations in the intercept of Cobb-Douglas production function, are associated with numerous factors, but particularly with the agroclimatic similarity index. This is consistent with Takeshima and Nasir (2017) who estimated 1) a similar model but only for Northern Nigeria, 2) that the agroclimatic similarity with the locations of public-sector plant breeding is an important determinant of agricultural productivity, and 3) that this variable serves as a good instrumental variable for the agricultural productivity variable.

4.1 Effects of agricultural productivity on NF-activities

Table 5 through Table 7 show the effects of agricultural productivity on capital and labor uses for NF-activities, differentiated between ANF- and NNF-activities.

The first rows in these tables show the effects of agricultural productivity. Results reveal various key patterns. The effects of higher agricultural productivity on all NF-activities are moderately positive, except the wage employment in the NF-sector (Table 5). A comparison of Table 6 and Table 7 suggests that effects are particularly more positive on ANF-activities, with significant effects on participation and allocation of factors, particularly family labor and non-fixed capital. In contrast, the effects are weaker for NNF-activities, with no effects on participation, and even negative effects on wage-employment. These patterns are consistent with our hypotheses that higher agricultural productivity induces shifts to ANF-activities, away from NNF-activities.

Only the effects on investment in fixed capital are greater for NNF-activities than for ANF-activities. This may suggest that the wealth generated from higher agricultural productivity remains an important financial source of fixed capital in the former NF-activities.

Table 5. Agricultural productivity and household diversification into NF-activities (aggregated; effects of one-standard deviation changes)

Variables	Capital stock of NF-enterprise	Expenses on NF-enterprise	Household members engaged in household NF-enterprise	Household membes working in NF wage job (person-days)	Whether the household engages in NF-activities
Agricultural productivity	.206*** (.056)	.124** (.050)	.177*** (.060)	-.067 (.051)	.069 (.068)
12 months rainfall	.058 (.106)	-.083 (.076)	.106 (.080)	-.133* (.070)	-.229*** (.076)
Wind at 10 meter height	-.013 (.038)	-.003 (.032)	.147*** (.034)	.114*** (.025)	.167*** (.033)
Solar radiation (average)	.279*** (.088)	.060 (.071)	.090 (.097)	-.185*** (.085)	-.191** (.088)
Slope	-.034** (.014)	-.035** (.017)	-.060*** (.017)	.000 (.014)	-.037** (.016)
Terrain ruggedness	.034* (.020)	.020 (.015)	.041* (.022)	.019 (.016)	.055*** (.014)
Soil cation exchange rate	.119*** (.037)	.034 (.034)	-.002 (.032)	-.059** (.029)	.071** (.030)
Soil acidity	-.176*** (.047)	-.052† (.035)	-.024 (.047)	.075* (.040)	-.089** (.042)
Soil component: Silt (%)	-.028 (.021)	-.045** (.022)	-.176*** (.027)	-.062*** (.019)	-.110*** (.021)
Soil component: Clay (%)	-.082** (.041)	.048† (.031)	.051 (.035)	.062** (.025)	-.034 (.031)
Soil component: Organic contents	.101† (.064)	.052 (.041)	.031 (.053)	-.023 (.048)	.127** (.051)
Soil component: Bulk density	.052* (.028)	.014 (.020)	.008 (.025)	.002 (.022)	.039† (.026)
Rainfall anomaly (PC 1)	-.082** (.041)	-.003 (.051)	.036 (.031)	-.093*** (.019)	.058** (.029)
Rainfall anomaly (PC 2)	-.014 (.018)	.009 (.017)	.011 (.022)	.075*** (.015)	-.020 (.020)
Household size (working age member)	.047* (.027)	.029* (.016)	.142*** (.020)	.170*** (.015)	.052*** (.015)
Household dependency ratio	-.016 (.018)	.030* (.015)	.140*** (.019)	.106*** (.015)	.097*** (.017)
Female household head (yes = 1)	.017 (.021)	-.007 (.012)	.028* (.017)	-.009 (.013)	-.003 (.019)
Age of household head	-.008 (.015)	-.010 (.010)	-.006 (.016)	.004 (.012)	-.059*** (.015)
Education of working-age members	.038* (.021)	.032 (.023)	-.052*** (.016)	-.014 (.014)	.019 (.016)
Own farm land (yes = 1)	.028* (.017)	.002 (.012)	.004 (.012)	.000 (.012)	.010 (.013)
ln (household asset)	.130*** (.018)	.074*** (.017)	.110*** (.014)	.149*** (.013)	.132*** (.015)
Household expenditure per capita	.066*** (.018)	.085*** (.015)	.094*** (.016)	.113*** (.012)	.089*** (.014)
EA income levels	.053*** (.018)	.017 (.015)	.066*** (.015)	.073*** (.014)	.094*** (.016)
EA incidence of funeral	.003 (.016)	-.020† (.012)	-.012 (.015)	-.049*** (.012)	-.001 (.015)
EA average expenses on funeral	.026† (.017)	.038† (.026)	.007 (.012)	.008 (.010)	.018 (.013)
Fertilizer parity price	.028 (.023)	-.014 (.019)	-.073*** (.024)	-.042** (.018)	-.170*** (.025)
New electricity in the community	.020 (.020)	-.008 (.012)	.013 (.011)	-.009 (.011)	.009 (.014)
ln (population density)	-.002 (.017)	.052** (.025)	.044** (.022)	.037** (.019)	.068*** (.025)
Distance to the nearest 20k town	-.018 (.013)	-.016 (.016)	-.005 (.018)	-.006 (.013)	.011 (.015)
Distance to the administrative center	-.046*** (.017)	-.033** (.015)	-.034* (.021)	.005 (.014)	-.041*** (.015)
Banks within the community	.027 (.024)	.083*** (.029)	.039** (.018)	.029† (.018)	.067*** (.019)
Distance to the nearest bank	-.010 (.011)	.024* (.015)	.008 (.019)	.025 (.021)	-.010 (.019)
Distance to the nearest urban center	-.170*** (.063)	-.161** (.073)	-.008 (.047)	.038 (.043)	-.088* (.050)
Distance to Lagos	.088** (.039)	.093** (.038)	.106** (.052)	.034 (.043)	.097** (.049)
Distance to Kano	-.081 (.058)	.083* (.047)	-.068* (.040)	.031 (.029)	-.060* (.036)
Distance to Nnewi	.163* (.094)	.116 (.122)	-.243*** (.053)	-.067† (.046)	-.172*** (.057)
=1 if Adamawa, Borno, Yobe states	.064** (.025)	.002 (.018)	-.061*** (.024)	-.061*** (.021)	-.072*** (.024)
Human epidemic disease	-.013*** (.004)	.013 (.023)	-.031** (.014)	-.019** (.008)	.017* (.009)
Government employment	-.048*** (.017)	-.041*** (.012)	-.062*** (.016)	.188*** (.014)	.091*** (.012)
Safety net	.040** (.019)	.030* (.015)	.021 (.017)	.017† (.011)	.037*** (.012)
Geopolitical zone dummy	Included	Included	Included	Included	Included
Year dummy	Included	Included	Included	Included	Included
Intercept	Included	Included	Included	Included	Included
No. observations	5575	5575	5575	5575	5575

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. EA = enumeration area. NF = non-farm. PC = principal component. 20k = 20,000 resident.

Table 6. Agricultural productivity and household diversification into ANF-activities

Variables	Capital stock of NNF- enterprise	Expenses on ANF- enterprise	Household members engaged in household ANF- enterprise	Household membes working in ANF wage job (person-days)	Whether the household engages in ANF- activities
Agricultural productivity	.066† (.042)	.190***(.075)	.193***(.063)	.067 (.056)	.090† (.060)
12 months rainfall	.039 (.062)	.034 (.047)	.040 (.075)	-.098 (.079)	-.236*** (.073)
Wind at 10 meter height	-.002 (.037)	.082* (.066)	.107***(.034)	.114***(.029)	.141*** (.030)
Solar radiation (average)	.205***(.071)	.184***(.015)	.069 (.080)	-.106 (.090)	-.157* (.082)
Slope	-.021* (.011)	-.024† (.023)	-.046***(.017)	-.017 (.015)	-.029* (.017)
Terrain ruggedness	.026 (.018)	.026 (.026)	.038* (.020)	.020 (.018)	.026† (.017)
Soil cation exchange rate	.054* (.031)	.046* (.043)	-.004 (.032)	-.042 (.033)	-.041 (.032)
Soil acidity	-.151***(.058)	-.123***(.035)	-.039 (.047)	-.038 (.049)	-.045 (.043)
Soil component: Silt (%)	-.031* (.016)	-.079** (.030)	-.131***(.024)	-.056** (.022)	-.115*** (.026)
Soil component: Clay (%)	-.073* (.039)	-.025 (.045)	.003 (.032)	.040† (.028)	.046† (.030)
Soil component: Organic contents	.010 (.081)	.054 (.022)	.110***(.043)	.022 (.044)	.157*** (.049)
Soil component: Bulk density	-.033 (.033)	.019 (.036)	.071***(.025)	.050** (.024)	.068*** (.024)
Rainfall anomaly (PC 1)	.016 (.024)	.003 (.018)	-.012 (.034)	-.068***(.021)	-.037 (.028)
Rainfall anomaly (PC 2)	-.002 (.024)	.011 (.017)	-.072***(.024)	.119***(.015)	.017 (.021)
Household size (working age member)	.062***(.018)	.040** (.021)	.043***(.016)	.059***(.015)	.038** (.016)
Household dependency ratio	.001 (.021)	.002 (.019)	.111***(.019)	.100***(.019)	.108*** (.018)
Female household head (yes = 1)	.043 (.030)	.035* (.015)	.052***(.018)	.024* (.014)	.040** (.019)
Age of household head	.038** (.019)	.014 (.018)	.031* (.016)	.026* (.016)	.003 (.015)
Education of working-age members	.004 (.014)	.006 (.015)	-.026† (.018)	-.059***(.012)	-.065*** (.017)
Own farm land (yes = 1)	-.004 (.013)	.032** (.021)	.014 (.014)	-.018 (.015)	.006 (.013)
ln (household asset)	.061***(.018)	.042** (.015)	.007 (.018)	.047***(.017)	.024† (.016)
Household expenditure per capita	.009 (.020)	.034** (.015)	.016 (.018)	.079***(.016)	.044*** (.015)
EA income levels	.002 (.014)	-.005 (.017)	.033** (.015)	.018 (.012)	.037** (.016)
EA incidence of funeral	-.001 (.009)	.009 (.013)	.002 (.014)	-.027* (.015)	.013 (.015)
EA average expenses on funeral	-.017† (.012)	-.018 (.028)	-.007 (.010)	.001 (.009)	.008 (.016)
Fertilizer parity price	-.017 (.014)	-.076***(.017)	-.149***(.025)	-.121***(.023)	-.250*** (.022)
New electricity in the community	.018 (.019)	.028† (.017)	.023† (.015)	-.007 (.010)	.005 (.011)
ln (population density)	.025 (.023)	.066***(.015)	.012 (.024)	.005 (.022)	.026 (.025)
Distance to the nearest 20k town	.007 (.010)	.013 (.013)	-.015 (.020)	.012 (.016)	.006 (.017)
Distance to the administrative center	-.035***(.011)	-.042***(.017)	-.049***(.017)	.009 (.018)	-.020 (.017)
Banks within the community	-.015 (.016)	.008 (.012)	.004 (.019)	.052***(.018)	.066*** (.018)
Distance to the nearest bank	.008 (.009)	-.022* (.052)	-.018 (.015)	.087***(.030)	.026† (.016)
Distance to the nearest urban center	.001 (.041)	-.060 (.035)	.039 (.047)	.081* (.046)	.104** (.050)
Distance to Lagos	-.024 (.043)	.092***(.035)	.074† (.051)	.029 (.048)	.050 (.049)
Distance to Kano	-.063* (.035)	-.033 (.069)	-.110***(.036)	-.038 (.033)	-.191*** (.039)
Distance to Nnewi	-.121***(.043)	-.135** (.018)	-.172***(.052)	-.066† (.046)	-.192*** (.054)
=1 if Adamawa, Borno, Yobe states	.044***(.017)	.025 (.020)	-.036† (.025)	-.065***(.024)	-.090*** (.022)
Human epidemic disease	-.011* (.005)	-.003 (.013)	-.008 (.019)	-.045***(.007)	.001 (.013)
Government employment	-.022** (.011)	-.019 (.014)	-.028** (.014)	-.028** (.014)	-.037** (.015)
Safety net	.007 (.009)	.012 (.075)	-.016 (.012)	.014 (.020)	.003 (.018)
Geopolitical zone dummy	Included	Included	Included	Included	Included
Year dummy	Included	Included	Included	Included	Included
Intercept	Included	Included	Included	Included	Included
No. observations	5575	5575	5575	5575	5575

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. EA = enumeration area. NF = non-farm. ANF = agriculture-related NF. NNF = non-agriculture-related NF. PC = principal component. 20k = 20,000 resident.

Table 7. Agricultural productivity and household diversification into NNF-activities

Variables	Capital stock of NNF- enterprise	Expenses on NNF- enterprise	Household members engaged in household NNF- enterprise	Household membes working in NNF wage job (person-days)	Whether the household engages in NNF- activities
Agricultural productivity	.206***(.056)	.059 (.046)	.132** (.055)	-.123** (.055)	.037 (.062)
12 months rainfall	.058 (.106)	-.104† (.069)	.121† (.077)	-.104† (.071)	-.034 (.072)
Wind at 10 meter height	-.013 (.038)	-.036 (.025)	.124***(.036)	.071*** (.026)	.101*** (.030)
Solar radiation (average)	.279***(.088)	-.008 (.072)	.117 (.090)	-.164** (.082)	-.007 (.092)
Slope	-.034** (.014)	-.028* (.016)	-.047***(.015)	.010 (.015)	-.037** (.016)
Terrain ruggedness	.034* (.020)	.012 (.011)	.015 (.020)	.011 (.015)	.033** (.016)
Soil cation exchange rate	.119***(.037)	.018 (.034)	.033 (.031)	-.047* (.029)	.078** (.031)
Soil acidity	-.176***(.047)	-.008 (.035)	-.054 (.046)	.115***(.035)	-.074* (.041)
Soil component: Silt (%)	-.028 (.021)	-.017 (.018)	-.114***(.025)	-.042** (.018)	-.083*** (.023)
Soil component: Clay (%)	-.082** (.041)	.061** (.029)	.024 (.037)	.053** (.026)	-.012 (.029)
Soil component: Organic contents	.101† (.064)	.034 (.040)	.013 (.055)	-.042 (.053)	-.032 (.051)
Soil component: Bulk density	.052* (.028)	.007 (.020)	-.038† (.026)	-.027 (.024)	-.010 (.025)
Rainfall anomaly (PC 1)	-.082** (.041)	-.004 (.055)	.030 (.032)	-.074*** (.023)	.092*** (.029)
Rainfall anomaly (PC 2)	-.014 (.018)	.005 (.018)	.033 (.023)	.020 (.016)	-.006 (.020)
Household size (working age member)	.047* (.027)	.016 (.015)	.133***(.020)	.174*** (.017)	.078*** (.014)
Household dependency ratio	-.016 (.018)	.032** (.014)	.072***(.018)	.070*** (.015)	.057*** (.017)
Female household head (yes = 1)	.017 (.021)	-.021** (.010)	.002 (.015)	-.026* (.014)	-.043*** (.017)
Age of household head	-.008 (.015)	-.017* (.010)	-.030** (.013)	-.010 (.013)	-.056*** (.014)
Education of working-age members	.038* (.021)	.032 (.024)	-.019 (.017)	.018 (.015)	.069*** (.016)
Own farm land (yes = 1)	.028* (.017)	-.010 (.012)	-.003 (.015)	.011 (.012)	.003 (.013)
ln (household asset)	.130***(.018)	.063***(.018)	.117***(.016)	.155*** (.013)	.144*** (.015)
Household expenditure per capita	.066***(.018)	.078***(.015)	.095***(.014)	.092*** (.013)	.080*** (.015)
EA income levels	.053***(.018)	.020 (.016)	.070***(.015)	.080*** (.016)	.105*** (.016)
EA incidence of funeral	.003 (.016)	-.025** (.011)	-.007 (.014)	-.044*** (.012)	-.016 (.014)
EA average expenses on funeral	.026† (.017)	.049** (.025)	.018 (.013)	.009 (.012)	.012 (.012)
Fertilizer parity price	.028 (.023)	.015 (.016)	-.012 (.022)	.020 (.020)	-.037† (.024)
New electricity in the community	.020 (.020)	-.019** (.009)	.006 (.012)	-.007 (.013)	-.004 (.015)
ln (population density)	-.002 (.017)	.030 (.026)	.062***(.022)	.042** (.020)	.059** (.024)
Distance to the nearest 20k town	-.018 (.013)	-.022† (.015)	-.009 (.017)	-.015 (.011)	-.003 (.015)
Distance to the administrative center	-.046***(.017)	-.019 (.014)	-.024 (.021)	.000 (.014)	-.027* (.014)
Banks within the community	.027 (.024)	.087***(.029)	.055***(.019)	.005 (.020)	.057*** (.019)
Distance to the nearest bank	-.010 (.011)	.035***(.013)	.021 (.020)	-.022 (.019)	-.030† (.019)
Distance to the nearest urban center	-.170***(.063)	-.151* (.080)	-.049 (.045)	-.001 (.041)	-.153*** (.048)
Distance to Lagos	.088** (.039)	.065† (.040)	.113* (.059)	.024 (.042)	.068 (.047)
Distance to Kano	-.081 (.058)	.104** (.046)	-.042 (.044)	.060* (.031)	.009 (.038)
Distance to Nnewi	.163* (.094)	.180† (.113)	-.137***(.044)	-.042 (.046)	-.134** (.053)
=1 if Adamawa, Borno, Yobe states	.064** (.025)	-.007 (.016)	-.019 (.024)	-.036* (.020)	-.045** (.021)
Human epidemic disease	-.013***(.004)	.015 (.024)	-.033***(.010)	.003 (.009)	.015 (.013)
Government employment	-.048***(.017)	-.037***(.012)	-.059***(.018)	.248*** (.016)	.121*** (.011)
Safety net	.040** (.019)	.028† (.018)	.026† (.016)	.012 (.015)	.021* (.012)
Geopolitical zone dummy	Included	Included	Included	Included	Included
Year dummy	Included	Included	Included	Included	Included
Intercept	Included	Included	Included	Included	Included
No. observations	5575	5575	5575	5575	5575

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. EA = enumeration area. NF = non-farm. NNF = non-agriculture-related NF. PC = principal component. 20k = 20,000 resident.

Our results also seem to suggest that higher agricultural productivity generally induces shifts from wage employment to household enterprises, regardless of the type of NF-activities. Although it is beyond the scope of this paper to investigate the underlying mechanism of this pattern, this may suggest that higher agricultural productivity induces greater entrepreneurship.

Results on the effects of other variables are generally consistent with theory. Greater household labor endowments and household wealth lead to more NF-activities; greater local population density and local income levels generally induce both types of NF-activities; and greater fertilizer subsidies are generally negatively associated with NF (unless they somehow raise agricultural productivity), consistent with earlier findings that fertilizer subsidies often crowd out the commercial fertilizer sector (Takeshima and Nkonya 2014). Some factors have more differential effects. Households with younger (older), or male (female) heads and more (less) educated members, are more engaged in NNF (ANF).

Distance to towns or urban centers has mixed effects. This is generally because while proximity to them can reduce transactions costs associated with NF, it can also raise more competition. Generally speaking, however, proximity to the nearest urban center is associated with more NNF-, rather than ANF-activities.

Effects on factor use in agriculture

Although not the focus of our study, effects of agricultural productivity on factor use in farming activities provide additional insights. Results on labor and variable capital use are shown in Table 12 in Appendix B.⁸ The results suggest that higher agricultural productivity also induces greater farm labor use (effects on variable capital are insignificant). The aforementioned effects of agricultural productivity on labor use in NF-activities are therefore not the results of simple labor allocation away from farming activities but rather likely lead to a net increase in rural employment.

4.2 Returns to capital and labor in NF-enterprises

Table 8 shows how agricultural productivity is associated with the returns to capital and labor in household NF-activities of different types. As already mentioned, because of high kurtosis of calculated return variables, we also report in Table 9 the results based on Neglog transformation of dependent variables.⁹

Table 8. Agricultural productivity and returns to capital and labor in NF-enterprises

Variables	Aggregated		Agriculture-related		Non-agriculture-related	
	Capital	Labor	Capital	Labor	Capital	Labor
Agricultural productivity	.008 (.035)	.040 (.078)	.284** (.123)	.236* (.133)	-.004 (.066)	-.108 (.080)
12 months rainfall	-.010 (.050)	.225** (.109)	-.014 (.187)	-.217 (.205)	-.011 (.045)	.223* (.121)
Wind at 10 meter height	-.004 (.021)	-.079† (.051)	-.040 (.075)	-.009 (.072)	-.003 (.018)	-.043 (.048)
Solar radiation (average)	-.050 (.082)	.203 (.163)	.230 (.224)	.154 (.227)	-.055 (.072)	.031 (.125)
Slope	-.003 (.031)	.012 (.027)	-.093† (.065)	-.032 (.049)	-.001 (.018)	.028 (.032)
Terrain ruggedness	-.010 (.020)	.010 (.021)	.059* (.031)	.042* (.024)	-.014 (.031)	-.010 (.020)
Soil cation exchange rate	.009 (.035)	-.059 (.057)	.061 (.067)	.023 (.058)	.007 (.029)	-.035 (.042)
Soil acidity	-.021 (.031)	.056 (.042)	-.125 (.110)	-.149* (.085)	-.017 (.041)	.104** (.050)
Soil component: Silt (%)	.023 (.026)	.016 (.031)	-.184*** (.055)	-.105** (.049)	.030 (.038)	.084** (.038)
Soil component: Clay (%)	-.013 (.027)	-.084** (.042)	.030 (.074)	-.019 (.055)	-.014 (.025)	-.055 (.042)
Soil component: Organic contents	-.035 (.064)	.113 (.112)	.044 (.119)	.285† (.183)	-.037 (.044)	-.115 (.111)
Soil component: Bulk density	-.002 (.017)	.028 (.034)	.077† (.048)	.039 (.059)	-.008 (.044)	-.026 (.030)

⁸Agricultural fixed capital is treated as exogenous in production function estimate and therefore not considered here.

⁹Neglog transformation (John & Draper 1980; Whittaker et al. 2005) transforms variable x as $sign(x) * \ln(abs(x) + 1)$, which has the advantage of handling zero and negative values, in addition to positive values.

Rainfall anomaly (PC 1)	.007	(.026)	.023	(.099)	-.040	(.087)	-.114	(.126)	.010	(.024)	.149*	(.088)
Rainfall anomaly (PC 2)	-.005	(.011)	-.068***	(.024)	-.006	(.064)	.055	(.069)	-.006	(.015)	-.052†	(.035)
Household working age members	-.001	(.009)	.009	(.017)	-.005	(.035)	-.017	(.042)	-.001	(.011)	.025	(.019)
Household dependency ratio	-.002	(.007)	-.054**	(.024)	.004	(.039)	-.022	(.036)	-.002	(.009)	-.033†	(.023)
Female household head (yes = 1)	.001	(.014)	.063***	(.020)	-.005	(.036)	.089†	(.058)	-.001	(.010)	-.015	(.034)
Age of household head	-.008	(.012)	.018	(.019)	-.003	(.022)	-.072†	(.047)	-.010	(.012)	.037	(.028)
Education of working-age members	-.023	(.025)	.030	(.028)	.036	(.041)	-.019	(.056)	-.022	(.029)	.047*	(.028)
Own farm land (yes = 1)	.019	(.022)	.040***	(.014)	.014	(.025)	.015	(.025)	.018	(.024)	.010	(.016)
ln (household asset)	.006	(.012)	-.043*	(.024)	-.095**	(.044)	.035	(.060)	.012	(.034)	-.032	(.031)
Household expenditure per capita	.006	(.009)	-.067***	(.020)	.057†	(.036)	.073***	(.031)	.006	(.013)	-.066***	(.023)
EA income levels	-.007	(.010)	-.011	(.017)	-.024	(.059)	-.029	(.039)	-.006	(.014)	.016	(.018)
EA incidence of funeral	-.017	(.017)	-.042	(.030)	.093**	(.047)	.020	(.048)	-.019	(.022)	-.032	(.023)
EA average expenses on funeral	.003	(.010)	-.037	(.047)	-.050†	(.034)	.126	(.162)	.003	(.007)	-.046	(.041)
Fertilizer parity price	.011	(.021)	.051**	(.025)	-.082*	(.046)	-.009	(.040)	.018	(.040)	.081***	(.028)
New electricity in the community	-.001	(.006)	.018	(.023)	.049	(.041)	.007	(.036)	-.003	(.019)	.017	(.022)
ln (population density)	-.011	(.021)	.040	(.038)	.093**	(.043)	-.005	(.067)	-.013	(.015)	.007	(.035)
Distance to the nearest 20k town	-.024	(.025)	.004	(.019)	.017	(.034)	-.013	(.039)	-.025	(.024)	.013	(.022)
Distance to the administrative center	.014	(.023)	.028†	(.018)	.027	(.030)	-.003	(.029)	.015	(.016)	.021	(.022)
Banks within the community	-.011	(.014)	-.084*	(.050)	.052	(.038)	.087*	(.051)	-.012	(.014)	-.111**	(.048)
Distance to the nearest bank	-.008	(.012)	-.031†	(.020)	.020	(.030)	-.007	(.028)	-.008	(.015)	-.021	(.023)
Distance to the nearest urban center	-.004	(.030)	.092	(.146)	-.075	(.122)	-.125	(.134)	-.005	(.026)	.127	(.118)
Distance to Lagos	.020	(.033)	-.008	(.046)	.218**	(.102)	.151†	(.093)	.011	(.057)	-.072	(.060)
Distance to Kano	.011	(.021)	-.027	(.103)	-.066	(.089)	-.074	(.119)	.014	(.024)	.018	(.090)
Distance to Nnewi	-.025	(.031)	-.183	(.196)	-.032	(.186)	.001	(.355)	-.020	(.041)	-.157	(.210)
=1 if Adamawa, Borno, Yobe states	-.026	(.031)	-.024	(.032)	-.022	(.044)	.005	(.053)	-.025	(.036)	.003	(.034)
Human epidemic disease	-.004	(.010)	.013†	(.009)	-.006	(.026)	-.020	(.018)	-.003	(.009)	.022***	(.008)
Government employment	-.001	(.009)	-.007	(.023)	-.005	(.030)	.017	(.024)	-.002	(.012)	-.108	(.080)
Safety net	-.001	(.007)	-.003	(.015)	.031	(.040)	.109**	(.052)	-.002	(.010)	-.027†	(.018)
Geopolitical zone dummy	Included		Included		Included		Included		Included		Included	
Year dummy	Included		Included		Included		Included		Included		Included	
Intercept	Included		Included		Included		Included		Included		Included	
No. observations		2871		2599		1296		1121		2871		2599

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. EA = enumeration area. NF = non-farm. PC = principal component. 20k = 20,000 resident.

Table 9. Agricultural productivity and returns to capital and labor in NF-enterprise (Neglog transformation of dependent variables)

Variables	Aggregated		Agriculture-related		Non-agriculture-related							
	Capital	Labor	Capital	Labor	Capital	Labor						
Agricultural productivity	.055	(.231)	.048	(.602)	1.719***	(.642)	1.006*	(.583)	-.241	(.256)	-.534	(.619)
12 months rainfall	-.117	(.333)	-.191	(.857)	1.227	(.863)	.778	(.973)	.156	(.389)	.372	(.944)
Wind at 10 meter height	-.098	(.147)	.072	(.403)	.185	(.407)	.178	(.400)	-.095	(.150)	-.049	(.395)
Solar radiation (average)	.129	(.352)	.386	(.965)	2.830***	(.937)	2.356**	(.977)	.209	(.419)	.706	(1.05)
Slope	.079	(.085)	.267	(.198)	-.250	(.220)	.027	(.156)	.099	(.091)	.316	(.223)
Terrain ruggedness	-.041	(.071)	-.014	(.161)	-.043	(.177)	.053	(.140)	-.095	(.073)	-.089	(.166)
Soil cation exchange rate	-.284*	(.148)	-.747**	(.336)	.281	(.352)	.127	(.330)	.018	(.150)	-.564*	(.313)
Soil acidity	.102	(.166)	.155	(.401)	-.990**	(.435)	-.805**	(.384)	.021	(.211)	.487	(.442)
Soil component: Silt (%)	.065	(.097)	.204	(.219)	-.585**	(.272)	-.684**	(.279)	.252***	(.095)	.844***	(.232)
Soil component: Clay (%)	.143	(.158)	.198	(.354)	.209	(.401)	.204	(.363)	-.196	(.152)	-.301	(.337)
Soil component: Organic contents	.133	(.258)	.794	(.580)	-.005	(.554)	.330	(.616)	-.051	(.299)	-.145	(.708)
Soil component: Bulk density	.269**	(.122)	.636**	(.315)	.652*	(.337)	.666**	(.332)	-.317***	(.115)	-.565**	(.271)
Rainfall anomaly (PC 1)	-.110	(.143)	-.080	(.351)	-.612†	(.389)	-.522	(.371)	.384***	(.145)	.571*	(.347)
Rainfall anomaly (PC 2)	-.054	(.105)	-.274	(.237)	.731**	(.323)	.824***	(.291)	-.139	(.119)	-.258	(.244)
Household working age members	.049	(.075)	.082	(.197)	-.316*	(.191)	-.206	(.197)	.066	(.079)	.154	(.181)
Household dependency ratio	-.047	(.064)	-.227	(.164)	-.332*	(.186)	-.099	(.185)	-.206***	(.080)	-.587***	(.188)
Female household head (yes = 1)	.183**	(.076)	.457**	(.180)	.290†	(.184)	.505***	(.160)	.048	(.091)	.141	(.196)
Age of household head	-.092†	(.059)	-.026	(.142)	.065	(.184)	-.081	(.154)	-.201***	(.070)	-.171	(.155)
Education of working-age members	-.061	(.070)	-.055	(.179)	-.028	(.212)	-.167	(.197)	.077	(.083)	.241	(.187)
Own farm land (yes = 1)	.088*	(.050)	.208*	(.116)	.252**	(.103)	.145†	(.100)	.034	(.067)	.100	(.142)
ln (household asset)	.046	(.075)	.139	(.178)	-.233	(.165)	-.157	(.160)	.345***	(.081)	.520***	(.194)
Household expenditure per capita	-.037	(.059)	-.448***	(.151)	.038	(.175)	.293*	(.165)	-.058	(.072)	-.476***	(.173)
EA income levels	-.081	(.065)	-.108	(.169)	.172	(.190)	.342*	(.203)	.046	(.077)	.170	(.179)
EA incidence of funeral	-.200***	(.064)	-.397**	(.167)	.373***	(.137)	.211	(.166)	-.267***	(.072)	-.484***	(.173)
EA average expenses on funeral	.030	(.051)	.130	(.131)	-.119	(.189)	-.093	(.249)	.095†	(.063)	.295**	(.144)
Fertilizer subsidy rates	-.108	(.101)	.192	(.256)	-.195	(.263)	-.098	(.234)	.542***	(.106)	1.200***	(.232)
New electricity in the community	.049	(.059)	.224*	(.133)	.132	(.176)	.203†	(.133)	-.030	(.054)	.009	(.134)
ln (population density)	.237***	(.087)	.504**	(.234)	.257	(.300)	-.182	(.277)	.087	(.106)	.287	(.267)
Distance to the nearest 20k town	.033	(.078)	.132	(.179)	.183	(.200)	.284†	(.185)	-.030	(.079)	.128	(.174)
Distance to the administrative center	.085	(.067)	.485***	(.146)	-.049	(.218)	-.233	(.204)	.122†	(.084)	.405**	(.178)
Banks within the community	-.077	(.075)	-.164	(.190)	.005	(.166)	.141	(.163)	-.036	(.095)	-.233	(.231)
Distance to the nearest bank	-.018	(.073)	-.147	(.158)	-.123	(.113)	-.045	(.130)	-.070	(.069)	-.177	(.168)
Distance to the nearest urban center	.074	(.170)	.063	(.473)	-.717	(.532)	-.287	(.450)	-.338†	(.209)	-.470	(.507)
Distance to Lagos	.060	(.198)	-.084	(.448)	.984*	(.505)	.237	(.442)	.049	(.227)	.134	(.498)
Distance to Kano	.336**	(.156)	1.254***	(.422)	-.031	(.543)	-.346	(.461)	.528***	(.169)	1.661***	(.401)
Distance to Nnewi	-.288†	(.188)	-.476	(.511)	-.029	(.522)	-.365	(.524)	.156	(.237)	.061	(.552)
=1 if Adamawa, Borno, Yobe states	-.067	(.099)	-.497**	(.251)	-.170	(.312)	.135	(.267)	.158†	(.110)	.034	(.272)
Human epidemic disease	-.016	(.057)	-.024	(.109)	.038	(.138)	-.061	(.123)	.018	(.055)	.101	(.110)
Government employment	.025	(.070)	.144	(.168)	.355**	(.155)	.420***	(.141)	.040	(.071)	.052	(.159)
Safety net	.031	(.045)	.074	(.127)	.127†	(.086)	.335***	(.087)	.032	(.048)	.058	(.142)
Geopolitical zone dummy	Included		Included		Included		Included		Included		Included	
Year dummy	Included		Included		Included		Included		Included		Included	
Intercept	Included		Included		Included		Included		Included		Included	
No. observations	2871		2599		1296		1121		2871		2599	

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. EA = enumeration area. NF = non-farm. PC = principal component. 20k = 20,000 resident.

The results in Table 8 and Table 9 suggest that higher agricultural productivity is associated more positively with returns to labor in ANF-activities, although it is insignificantly associated with returns to factors in NNF-activities. The effects on returns to labor in ANF-activities are positive with or without Neglog transformation, suggesting the robustness, while robustness is somewhat weak for NNF-activities. These results are generally consistent with the above findings; higher agricultural productivity raises returns to labor in ANF-activities and induces more engagement in ANF-activities. Furthermore, the effects on returns to labor are stronger in ANF-activities than in NNF-activities, and thus involve some shifts in labor use from the latter to the former type of activities.

How can we interpret insignificant or somewhat negative effects of agricultural productivity on returns to capital, such as those in NNF-activities, despite the positive effects on the investments into factors as described above? In this case, higher agricultural productivity may mostly induce investments by mitigating the liquidity constraints rather than raising the returns to investment.

The effects of other explanatory variables are not our main focus and are generally difficult to interpret, as they reflect the combined effects of various mechanisms. They, however, control for the sources of variations in returns that are not accountable for agricultural productivity.

4.3 Robustness checks

As was mentioned above, we further check the robustness of (3) in the three ways (a) ~ (c).

(a) Using partial labor productivity instead of TFP

Agricultural productivity has sometimes been measured by partial labor productivity, which is the agricultural incomes divided by farm labor use (Amare et al. 2018; Djido & Shiferaw 2018). For robustness check, we also estimate the model by using partial labor productivity in place of TFP. Table 13 and Table 14 in Appendix C summarize the coefficients for the labor productivity variable. The results are generally consistent with our main findings emanating from the empirical analysis; higher agricultural productivity has greater effects on participation in and factor-uses in ANF-activities, rather than other types of NF-activities, and does so by raising returns to these factors, rather than simply mitigating the liquidity constraints.

(b) Potential of unobserved time-invariant fixed effects in v_{it}

Being estimated through (2), \tilde{c}_i implicitly contains the effect of unobserved time-invariant household fixed effects. There may, however, still be unobserved time-invariant household fixed effects embedded in v_{it} in (3), which may be correlated with covariates including \tilde{c}_i . In such a case, the estimated effects of \tilde{c}_i could be inconsistent. We therefore re-estimate (3) as in (1) and (2), i.e., estimating (3) through fixed-effects panel, obtain household fixed effects, and regress them on time-invariant variables including \tilde{c}_i . The coefficients on \tilde{c}_i can therefore be interpreted as consistent estimates of the effects on N_{it} . As are shown in Table 15 in Appendix C, the patterns of obtained results are largely consistent with our primary findings; in particular, higher agricultural productivity generally induces NF-activities, by investments into capital as well as labor uses, although the differences between ANF- and NNF-activities become less pronounced.

(c) Truncated nature of some indicators of N_{it}

Some variables N_{it} are truncated at zero and skewed toward the right of the distributions. The results from Table 5 through Table 7 could have been influenced by such data characteristics. We therefore re-estimate (3) using Box-Cox double-hurdle models, originally developed by Cragg

(1971) and generalized by Yen (1993), which are both less restrictive than other methods like Tobit regression, and allow more flexibility for the effects of covariates on non-truncated data. Non-truncated data are modified through Box-Cox transformation, as

$$N_{it}^* = \frac{(N_{it})^\lambda - 1}{\lambda}. \quad (4)$$

We use $\lambda = 0, 0.25, 0.5, 0.75$ and 1 . If $\lambda = 1$, we have a standard double-hurdle model, while $\lambda = 0$ indicates a double-hurdle model with non-truncated data in natural-log. Estimating by various λ allows us to see the robustness of the results, and also to obtain some estimates where a standard double-hurdle model fails to converge.

Table 16 in Appendix C summarizes the results, showing the effects of agricultural productivity on the probability of N_{it} being positive values, and the effects of agricultural productivity on non-truncated values, corresponding to each value of λ . Again, these results confirm our main messages, that higher agricultural productivity generally induces NF-activities, by investments into capital as well as labor uses, and these effects are stronger for ANF-activities.

5 Conclusions

African countries such as Nigeria have experienced economic transformation in the last few decades, in terms of declining employment and GDP-shares of the agricultural sector. Despite such growth, however, both poverty and unemployment remain high in the country. At the same time, agricultural productivity in Nigeria has remained low, albeit with recent catchup. These conditions pose important questions, such as, for reducing poverty and rural unemployment, should the government focus on shifting more support to the NF sector, instead of supporting productivity growth in the agricultural sector?

A knowledge gap exists in countries such as Nigeria on how agricultural productivity contributes to the relations between economic transformation and poverty, rural employment and entrepreneurship in the nonfarm sector. In particular, the evidence has been scarce in these countries on how agricultural productivity growth relates to households' engagements in, as well as returns to NF-activities, and if so, how it affects the characteristics of these activities.

In this paper, we attempted to fill this knowledge gap using nationally representative household data, as well as various agroclimatic data from Nigeria. In doing so, we took advantage of the data to carefully construct the variables characterizing the nonfarm activities in terms of sector orientation, entrepreneurship, and factor intensity. We also estimated TFP as an indicator of household agricultural productivity, using agroclimatic similarity with plant breeding locations as an instrument.

Our findings suggest that agricultural productivity growth in Nigeria, including the growth in terms of TFP, generally leads to greater rural employment in both farming and the NF-sector. Agricultural productivity growth has differential effects on farm households' engagements into NF-activities. Specifically, it leads to more growth of household NF activities that are agriculture-oriented, relative to NF activities that are less agriculture-oriented. Furthermore, higher agricultural productivity raises the returns to capital and labor for agriculture-oriented NF activities. These conditions suggest that, raising agricultural productivity in countries such as Nigeria still leads to further growth of the nonfarm sector, and in ways that improve the NF sector's contribution to overall economic growth and reductions of poverty and unemployment.

Finally, our findings also highlight the importance of understanding the heterogeneity in NF-activities. In particular, distinctions are important in terms of their sector orientations (agricultural versus nonagricultural), entrepreneurship (enterprise versus wage employment), and factor intensity (capital versus labor).

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Appendix A: Agroclimatic similarity with plant breeding locations

Agroclimatic similarity with plant breeding locations is constructed in the following way.¹⁰ Following Takeshima & Nasir (2017), the raw similarity index for household i with respect to the breeding institute B ($D_{i,B}$) is,

$$D_{i,B} = - \sum_{\theta} w_{\theta} (|X_i^{\theta} - X_B^{\theta}|) \quad (\text{A1})$$

where X_i^{θ} and X_B^{θ} are the values of key agroclimatic parameters θ in areas where farm household i and breeding institute B is located, respectively. $|X_i^{\theta} - X_B^{\theta}|$ is the absolute deviation. Weight for each θ (w_{θ}) captures the effect of the similarity of θ for the overall similarity with B . Following Bazzi et al. (2016) and Takeshima & Nasir (2017), sample average values of θ are used as w_{θ} , so that absolute deviations are standardized relative to the unit of θ . $D_{i,B}$ is therefore the sum of the absolute differences in the standardized values of parameter θ between i with respect to B . With the negative “-” added in front of the summation operator in (A1), an increase in $D_{i,B}$ indicates the increase in agroclimatic similarity.

The overall similarity index for the household i (D_i) is then,

$$D_i = \max_B (D_{i,B}) \quad (\text{A2})$$

which is the maximum similarity index among all plant breeding institutions. D_i is then standardized so that it is distributed between 0 and 1, with 0 the least similar and 1 the most similar. This is simply for the ease of interpreting D_i .

¹⁰The description here draws largely on Takeshima & Nasir (2017).

Appendix B. Agricultural production function and instrumenting function

Table 10. Cobb-Douglas production function (fixed effects panel) (equation (1))

Variables	Coef.	Std.err
Agricultural capital	.116***	(.018)
Labor	.109***	(.015)
Area	.059***	(.010)
Animal traction	.027*	(.016)
Irrigation	.879***	(.200)
Other cash expenses on inputs and services	.063***	(.008)
Annual rainfall	.000	(.000)
Year dummy	Included	
Geopolitical zone dummy	Included	
Constant	Included	
Sample	5575	
R-square	.152	
P-value (H ₀ : variables are jointly insignificant)	.000	

Source: Authors.

Table 11. Instrumenting function (equation (2))

Dependent variable = time-invariant household fixed effects (\hat{c}_i) obtained from estimation Table 10	Coef.	(Std.err)
Variables		
Agroclimatic similarity	.063†	(.042)
12 months rainfall	-.706***	(.141)
Wind at 10 meter height	-.164**	(.069)
Solar radiation (average)	-.800***	(.121)
Slope	.148***	(.026)
Terrain ruggedness	-.073**	(.031)
Soil cation exchange rate	-.320***	(.057)
Soil acidity	.310***	(.072)
Soil component: Silt (%)	.092**	(.041)
Soil component: Clay (%)	.203***	(.064)
Soil component: Organic contents	-.243**	(.096)
Soil component: Bulk density	-.143***	(.043)
Rainfall anomaly (PC 1)	-.016	(.054)
Rainfall anomaly (PC 2)	.334***	(.061)
Household size (working age member)	.113***	(.028)
Household dependency ratio	.134***	(.024)
Female household head (yes = 1)	-.184***	(.033)
Age of household head	-.088***	(.029)
Average education of working-age members	-.110***	(.040)
Own farm land (yes = 1)	-.016	(.020)
ln (household asset)	.116***	(.039)
Household expenditure per capita	.111***	(.038)
EA income levels	-.091***	(.034)
EA incidence of funeral	.008	(.025)
EA average expenses on funeral	-.042†	(.028)
Fertilizer parity price	-.124***	(.042)
New electricity in the community	-.078***	(.028)
ln (population density)	-.117**	(.057)
Distance to the nearest 20k town	.093***	(.030)
Distance to the administrative center	.011	(.030)
Banks within the community	-.133***	(.032)
Distance to the nearest bank	-.026	(.020)
Distance to the nearest urban center	.607***	(.075)
Distance to Lagos	-.599***	(.140)
Distance to Kano	-.072	(.066)
Distance to Nnewi	-.279***	(.081)
=1 if Adamawa, Borno, Yobe states	-.059	(.044)
Human epidemic disease in the community	.001	(.026)
Household member employed in the government	-.149***	(.036)
Value of safety net received (EA sample average)	.005	(.031)
Intercept	Included	
No. observations	5575	

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. EA = enumeration area. PC = principal component. 20k = 20,000 resident.

Table 12. Agricultural productivity and factor uses in agriculture

Variables	Labor		Other expenses	
Agricultural productivity	.266***	(.069)	.040	(.078)
12 months rainfall	.202**	(.082)	.047	(.056)
Wind at 10 meter height	-.006	(.035)	-.055	(.052)
Solar radiation (average)	.284***	(.089)	.010	(.075)
Slope	-.038**	(.017)	-.016	(.021)
Terrain ruggedness	.007	(.019)	.006	(.016)
Soil cation exchange rate	.086***	(.033)	.035	(.039)
Soil acidity	-.089**	(.042)	.000	(.058)
Soil component: Silt (%)	-.038*	(.023)	.017	(.019)
Soil component: Clay (%)	-.025	(.029)	-.055	(.039)
Soil component: Organic contents	.082*	(.050)	-.070*	(.036)
Soil component: Bulk density	.041†	(.025)	-.020	(.019)
Rainfall anomaly (PC 1)	.036	(.026)	.064**	(.026)
Rainfall anomaly (PC 2)	-.246***	(.027)	-.049*	(.028)
Household size (working age member)	.216***	(.019)	.028†	(.019)
Household dependency ratio	.078***	(.020)	.015	(.014)
Female household head (yes = 1)	-.043***	(.016)	.001	(.017)
Age of household head	.058***	(.014)	.005	(.014)
Average education of working-age members	-.030**	(.013)	.017	(.020)
Own farm land (yes = 1)	-.021*	(.012)	.018	(.015)
ln (household asset)	-.089***	(.015)	.028†	(.019)
Household expenditure per capita	-.064***	(.016)	.049***	(.012)
EA income levels	-.061***	(.016)	.012	(.012)
EA incidence of funeral	.054***	(.016)	-.018	(.014)
EA average expenses on funeral	-.042***	(.011)	-.006	(.006)
Fertilizer parity price	.055***	(.021)	-.061***	(.013)
New electricity in the community	-.009	(.011)	-.014**	(.006)
ln (population density)	-.011	(.022)	-.002	(.048)
Distance to the nearest 20k town	-.021†	(.014)	-.028*	(.016)
Distance to the administrative center	.023	(.016)	-.007	(.020)
Banks within the community	.038**	(.018)	-.004	(.024)
Distance to the nearest bank	.022	(.015)	-.009	(.013)
Distance to the nearest urban center	-.006	(.049)	.034	(.050)
Distance to Lagos	.064	(.047)	.066	(.067)
Distance to Kano	.004	(.034)	-.051†	(.033)
Distance to Nnewi	.056	(.052)	-.080*	(.048)
=1 if Adamawa, Borno, Yobe states	-.050**	(.024)	-.024	(.020)
Human epidemic disease in the community	.023**	(.012)	.000	(.010)
Household member employed in the government	-.036**	(.014)	.001	(.023)
Value of safety net received (EA sample average)	-.009	(.014)	-.006	(.006)
Geopolitical zone dummy	Included		Included	
Year dummy	Included		Included	
Intercept	Included		Included	
No. observations	5575		5575	

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. EA = enumeration area. PC = principal component. 20k = 20,000 resident.

Appendix C. Robustness checks

Table 13. Estimates when partial labor productivity is used instead of TFP (NF-activities)

Variables	Capital stock of NF-enterprise		Expenses on NF- enterprise		Household members engaged in household NF-enterprise		Household membes working in NF-wage job (person-days)		Whether the household engages in NF- activities	
All NF-activities	-.015	(.024)	-.002	(.022)	.045**	(.021)	.013	(.014)	.024	(.020)
ANF-activities	.009	(.013)	.033*	(.018)	.077***	(.019)	.062***	(.016)	.061***	(.021)
NNF-activities	-.015	(.022)	-.015	(.016)	.018	(.023)	-.021	(.015)	.003	(.019)

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. NF = non-farm. ANF = agriculture-related NF. NNF = non-agriculture-related NF. TFP = total factor productivity.

Table 14. Estimates when partial labor productivity is used instead of TFP (returns from NF-activities)

Variables	Aggregated				Agriculture-related				Non-agriculture-related			
	Capital		Labor		Capital		Labor		Capital		Labor	
Original	-.014	(.015)	.040†	(.027)	.028	(.049)	.025	(.037)	-.016	(.015)	.001	(.026)
Neglog	-.013	(.027)	-.008	(.026)	.009	(.040)	.025	(.044)	-.054**	(.025)	-.041†	(.026)

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. NF = non-farm. TFP = total factor productivity.

Table 15. Estimates with panel fixed effect for equation (3)

Variables	Capital stock of NF-enterprise		Expenses on NF-enterprise		Household members engaged in household NF-enterprise		Household membes working in NF wage job (person-days)		Whether the household engages in NF- activities	
All NF-activities	.193***	(.056)	.186*	(.099)	.362***	(.091)	-.052	(.116)	.232***	(.080)
ANF-activities	.011	(.108)	.149†	(.094)	.296***	(.095)	-.010	(.127)	.187**	(.078)
NNF-activities	.193*	(.102)	.143	(.101)	.236**	(.100)	-.058	(.124)	.217**	(.087)

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%. NF = non-farm. ANF = agriculture-related NF. NNF = non-agriculture-related NF.

Table 16. Robustness check through Box-Cox double-hurdle

Variables	Capital stock of NF- enterprise	Expenses on NF-enterprise	Household members engaged in household NF-enterprise	Household membes working in NF wage job (person-days)
<i>All NF</i>				
Double-hurdle model – probability	.272** (.116)	.133** (.058)	.246** (.106)	-.206* (.114)
Double-hurdle model – truncated regression ($\lambda = 1$)	NA	NA	.212* (.116)	.152 (.174)
Double-hurdle model – combined partial effects	NA	NA	.182*** (.064)	-.018 (.049)
Truncated regression in Box-Cox double hurdle				
$\lambda = 0$	.356*** (.077)	.250*** (.077)	.188** (.076)	.101 (.093)
$\lambda = 0.25$	.268*** (.072)	.230*** (.073)	.190*** (.070)	-.093* (.049)
$\lambda = 0.5$	.298*** (.067)	.239*** (.068)	.200*** (.069)	-.081† (.050)
$\lambda = 0.75$	NA	.261*** (.080)	.210*** (.072)	-.068 (.055)
<i>ANF</i>				
Double-hurdle model – probability	.214** (.105)	.347*** (.061)	.178* (.099)	.078 (.133)
Double-hurdle model – truncated regression ($\lambda = 1$)	NA	NA	.488* (.288)	1.763*** (.607)
Double-hurdle model – combined partial effects	NA	NA	.144** (.065)	.147** (.062)
Truncated regression in Box-Cox double hurdle				
$\lambda = 0$	.252* (.133)	.281** (.128)	.223* (.118)	.451** (.177)
$\lambda = 0.25$	.176*** (.061)	.214*** (.061)	.169*** (.062)	-.012 (.055)
$\lambda = 0.5$	.166*** (.058)	.268*** (.065)	.193*** (.066)	.026 (.059)
$\lambda = 0.75$	NA	.375*** (.093)	.243*** (.081)	.085 (.076)
<i>NNF</i>				
Double-hurdle model – probability	.272** (.116)	-.038 (.052)	.181* (.101)	-.155† (.107)
Double-hurdle model – truncated regression ($\lambda = 1$)	NA	NA	.540** (.267)	-.258 (.193)
Double-hurdle model – combined partial effects	NA	NA	.138** (.055)	-.093* (.053)
Truncated regression in Box-Cox double hurdle				
$\lambda = 0$	.356*** (.077)	.069 (.094)	.149* (.080)	-.083 (.084)
$\lambda = 0.25$	.268*** (.072)	.151** (.068)	.135** (.064)	-.102* (.054)
$\lambda = 0.5$	.756*** (.200)	.136** (.066)	.144** (.064)	-.112** (.056)
$\lambda = 0.75$	NA	.144* (.083)	.165*** (.069)	-.123** (.061)
No. observations	5575	5575	5575	5575

Source: Authors.

Note: Asterisks indicate statistical significance *** 1% ** 5% * 10% † 15%.

NA = results unobtainable due to the failure of convergence.

NF = non-farm. ANF = agriculture-related NF. NNF = non-agriculture-related NF.

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