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Effects of Public Expenditures on Agriculture at Subnational Levels on Households' Welfare and Economic Resilience in Nigeria

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Abstract

Agricultural development has long been considered an important driver of overall economic development in developing countries such as Nigeria. Whether increasing public expenditures on agriculture (PEA) can directly improve broad dimensions of household well-being has continued to be debated. In addition, there has been growing interest in the economic flexibility of households to switch between nonfarm and farming activities. Such flexibility can potentially enhance the resilience of households to shocks like the COVID-19 pandemic in today's rapidly changing socioeconomic environments. Direct evidence of the impact of PEA on broad development outcomes is also important in informing regional initiatives aiming to use PEA as an instrument for overall food security enhancement and poverty reduction in Africa. Using state- and local government area (LGA)-level PEA figures and household data in Nigeria, this study aims to provide initial evidence at the household level in Nigeria.

The findings suggest that greater PEA shares have positive effects on various development outcomes at the household level, including consumption, poverty reduction, nonfarm capital investments, and household dietary diversity. The findings also suggest that greater PEA shares are likely to help farm households enhance their economic flexibility. These findings are consistent with the hypotheses of positive linkages between PEA and agricultural outcomes, and linkages between agricultural and nonagricultural outcomes, often advocated in the literature. PEA should be increased by increasing its *share* of total public expenditures through conscious efforts to reallocate existing resources, rather than trying to increase it by increasing the overall *size* of public expenditures. Furthermore, it remains important to identify the appropriate sources (for example, spending by LGA or state) and types of PEA (for example, recurrent or capital spending) for particular development outcomes.

Keywords: public expenditures, panel data analysis, household-level analysis, development outcomes, flexibility, Nigeria

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1 INTRODUCTION

Agricultural development has long been considered an important driver of overall economic development. Conventional literature has provided theoretical arguments for such linkages (for example, Johnston and Mellor 1961; Haggblade, Hazell, and Brown 1989). Recent literature has continued to provide empirical support for these linkages (Bustos, Caprettini, and Ponticelli 2016; McArthur and McCord 2017; Gollin, Hansen, and Wingender 2018; Lee 2018; McArthur and Sachs 2019; Loizou et al. 2019; Baffes, Kshirsagar, and Mitchell 2019). In addition, there has been growing interest in resilience (for example, Barrett and Constas 2014; Upton, Cissé, and Barrett 2016), which can be measured in various ways, including via indicators such as the flexibility of households in shifting between economic activities. Resilience is also relevant in today's rapidly changing socioeconomic environment, due to shocks like the outbreak of the COVID-19 pandemic, in which households are required to make rapid adjustments in their production activities, including significant shifts between nonfarm activities and farming activities such as subsistence food crop production.

However, direct evidence of the impact of policy variables such as public expenditures on agriculture (PEA) on these outcomes at the household level is thin in developing countries such as Nigeria. The direct evidence of PEA impact on broad development outcomes is also important in informing regional initiatives (such as those advocated and supported by the Comprehensive Africa Agriculture Development Programme [CAADP]) aiming to use PEA as an instrument for overall food security enhancement and poverty reduction in Africa.

This study aims to help fill this evidence gap by using the data on PEA and overall expenditures by both state and local government areas (LGAs) over time, as well as nationally representative household-level panel data, to estimate the effects of PEA on various household-level development outcomes such as consumption, poverty, private investments, and dietary diversity. We also estimate the effects of PEA on the flexibility of households to switch between nonfarm activities and farming activities, an indicator of resilience that has been used in the recent production economics literature.

In addition to providing policy-relevant evidence in Nigeria, this study also contributes to various strands of literature. First, the study complements the aforementioned literature on agriculture–nonagricultural development linkages by providing further evidence from the perspective of linkages between PEA and broad development outcomes. Second, similar to our companion paper (Takeshima, Smart, et al. 2020), this study contributes to the literature on public expenditures (for example, Fan, Hazell, and Thorat 2000; Fan and Zhang 2008; Mogues and Benin 2012; Almanzar and Torero 2017; Anderson et al. 2017, 2018). Third, the study contributes to the literature on production economics, including research on economic flexibility and economies of scope (for example, Renner, Glauben, and Hockmann 2014; Nguyen 2017; Takeshima, Hatzenbuehler, and Edeh 2020).

This paper is structured in the following way. Section 2 discusses the conceptual and theoretical framework. Section 3 discusses data, and section 4 discusses empirical methodologies. Section 5 presents descriptive statistics. Section 6 presents and discusses the empirical results, and section 7 concludes.

2 CONCEPTUAL AND THEORETICAL FRAMEWORK

The potential linkages between PEA and various household-level economic outcomes can emerge through several channels, including (a) PEA → agricultural outcomes → nonagricultural outcomes and (b) PEA → public expenditures on nonagricultural sectors (PENA) → nonagricultural outcomes. While PEA is generally not the primary tool used for overall economic growth, the question of whether PEA contributes to inclusive growth has attracted much attention. Our study does not separately test these channels, but rather focuses on showing what the overall effects are in the context of Nigeria during the studied period, through reduced-form regressions, as described below.[1]

(a) PEA → agricultural outcomes → nonagricultural outcomes

For channel (a), we briefly discuss the second part of the linkage (agricultural outcomes → nonagricultural outcomes), as our companion paper, Takeshima, Smart, et al. (2020), discusses the first part of the linkage (PEA → agricultural outcomes) in detail.

The effects of agricultural growth on overall economic growth continue to be widely documented in the latest studies, including the effects of yield-enhancing technologies (McArthur and McCord 2017; Gollin, Hansen, and Wingender 2018), the effects of labor-saving varieties on structural transformation (Bustos, Caprettini, and Ponticelli 2016), and the economywide effects of aid to agriculture (McArthur and Sachs 2019). Elements of such linkages are expected to emerge through backward and forward linkages with agricultural production activities, including household-level and small-to-medium-scale enterprises for agricultural input sales, mechanization of custom-hiring service provision, food processing, transportation, and retailing (Haggblade, Hazell, and Brown 1989), where higher agricultural productivity can induce private capital investments for nonfarm household enterprises or labor productivity increases in nonfarm sectors (for example, Takeshima, Amare, and Mavrotas 2018). Evidence also remains persistent for the "food problem," whereby lower food productivity induces households to continue allocating more resources to subsistence food production (for example, Lee 2018), because the agricultural sector continues to be the provider of "basic needs" (Loizou et al. 2019). Also, despite growing market integration, local food prices still depend considerably on local agricultural production factors (for example, Baffes, Kshirsagar, and Mitchell 2019), due to market imperfections and the resilience of traditional attitudes toward exchange in rural agricultural settings in the Global South (Carlson 2018). These sets of evidence are also consistent with the claimed effects on poverty (for example, Christiaensen, Demery, and Kuhl 2011).

These studies suggest that if PEA contributes to household-level agricultural outcomes, it can also contribute to broader, nonagricultural household-level outcomes. Some studies have also shown more directly that public expenditures on agricultural research and extension, for example, have some of the largest effects on poverty reduction (for example, Fan, Hazell, and

[1] Certain other issues associated with the effects of PEA on household-level outcomes are also discussed in Takeshima, Smart, et al. (2020), which focuses on agricultural outcomes, and are not repeated here. Relevant measures of PEA can vary in terms of spending share (share of PEA in total public expenditures), size of spending, types (for example, recurrent and capital), tiers of government (state governments and lower-tier local governments), as well as spatiotemporal effects (for example, spillover across local governments and time lags of effects). Generally, Takeshima, Smart, et al. (2020) argue that evidence of effects on household-level outcomes generally remains scarce and theoretically ambiguous, motivating empirical investigations in the particular context of countries such as Nigeria. Similar empirical motivations also apply to this study, which focuses on households' nonfarm outcomes.

Thorat 2000; Fan and Zhang 2008). An increasing body of literature has also supported generally positive agriculture–nutrition linkages (Ruel, Quisumbing, and Balagamwala 2018; Fan, Yosef, and Pandya-Lorch 2019; Bellows et al. 2020; Amare, Balana, and Ogunniyi 2020), including demonstrating the positive effects of agricultural spending (such as spending on input subsidies) on nutritional outcomes (for example, Harou 2018).

However, the literature is also split with regard to whether agriculture has positive effects on nonfarm sectors. When the agricultural sector acts more as a competitor to nonfarm activities, higher agricultural productivity (which raises the cost of competing production factors such as labor and capital) can negatively affect nonfarm sectors (for example, Matsuyama 1992; Foster and Rosenzweig 2004). In such a case, even if PEA has positive effects on agricultural outcomes, its effects on overall incomes may be offset by the potentially negative effects on nonfarm outcomes.

(b) PEA → PENA → nonagricultural outcomes

The effects produced through channel (b) are ambiguous. Budgetary trade-offs (an increase in the agricultural budget directly reduces the budget for other sectors) generally appear to be common in the budget process (Mogues and Benin 2012). In terms of indirect effects, the literature on the role of PEA on PENA is generally scarce. For example, effective large-scale farming projects (potentially supported through greater PEA) can lead to greater local and/or national tax revenues (Deininger and Byerlee 2012), due to increased land values and land tax revenues, for example. Similarly, increased imports of inputs (fertilizer, chemicals, and machinery and parts) may contribute to increased tariff revenues, which can potentially increase fiscal space for PENA as well. However, in Africa south of the Sahara, evidence has leaned more toward the opposite conclusion: greater tax revenues have been associated with a reduced agricultural share of the economy (Andersson and Lazuka 2019). Also, if agricultural spending can successfully grow the agricultural sector, revenues from food import tariffs may actually be reduced (though the evidence is generally limited).

The budgetary trade-offs between PEA and PENA can potentially offset the direct effects of PEA on certain outcomes, but in complex ways. In Rwanda and Tanzania, PENA in the social sector (for example, health, education, and infrastructure) had positive effects on household consumption, but these effects were biased in favor of well-off households rather than poorer households (Almanzar and Torero 2017). Similarly, Anderson et al. (2017), through meta-regression of 84 separate studies, find that social spending (spending on health, education, social welfare, housing, and consumption, among other categories) generally has had regressive effects, benefiting higher-income households and widening inequality. Anderson et al. (2017) suggest that these outcomes are likely due to the fact that much of the spending has been captured by the middle-income class rather than the lower-income class, among other factors. The effects of government spending (mostly PENA) on poverty reduction have also remained generally limited (Anderson et al. 2018). These generally regressive effects of PENA suggest that if PEA has budgetary trade-offs with PENA, PEA may potentially have more progressive effects, benefiting the poor relatively more. However, the size of these effects in absolute terms remains unclear.

Challenges may also remain in establishing the linkage between PENA and nonagricultural outcomes. While it is beyond the scope of this paper to discuss this linkage, some of the key challenges reported in the literature are also relevant for PEA. For example, increased public expenditures could sometimes lead to rent-seeking activities that cause general misallocation of production factors in the market (Reinikka and Svensson 2004). Stasavage (2005) discusses the political, rather than economic, influence on educational spending and

education outcomes in Africa south of the Sahara. Decentralization through increased spending by lower administrative units has also had mixed effects on corruption (Lederman, Loayza, and Soares 2006), with more negative effects where political competition is inadequate (Albornoz and Cabrales 2013). Lastly, similar to the case of the effects of PEA on agricultural outcomes, PENA has also sometimes crowded out, rather than crowded in, private investment, including in nonfarm sectors (for example, Bahal, Raissi, and Tulin 2018).

As discussed briefly above, the expected effects of PEA on overall broader household-level economic outcomes are ambiguous and thus pose empirical questions. This motivates our empirical analyses, which we describe below.

3 DATA

This study uses household-level data, state- and LGA-level public expenditure data, and weather data in Nigeria. Household-level data are four rounds of panel data from the Living Standards Measurement Study–Integrated Surveys on Agriculture (LSMS-ISA) collected by the National Bureau of Statistics of Nigeria (NBS) and the World Bank in 2010/2011, 2012/2013, 2015/2016, and 2018/2019. The data consist of panel data from 5,000 nationally representative households for the first three rounds, and from approximately 1,507 of these original 5,000 households in the last round (NBS and World Bank 2016, 2019). The 5,000 panel households consist of 10 households that were randomly selected in wave 1 from each of 500 enumeration areas (also randomly selected from among all enumeration areas defined by the NBS) and reinterviewed in waves 2 and 3. The 1,507 households in wave 4 were selected from 159 of the original 500 enumeration areas (NBS and World Bank 2019). Approximately 60 percent of the samples in each wave are agricultural households.

State- and LGA-level expenditure data for all of Nigeria's 37 states and 774 LGAs are from annual statistical bulletins and reports from the Central Bank of Nigeria and from annual surveys conducted jointly by the Federal Ministry of Finance, the Central Bank of Nigeria, NBS, and the Nigerian Communications Commission, which are available for the period 2007 to 2015 (Nigeria, Federal Ministry of Finance 2015 and previous years). The data include information on expenditures by type (recurrent and capital) and function (economic affairs, as well as general public services, defense, public order and safety, environmental protection, etc.). The spending on agriculture, PEA, is classified as part of the spending on economic affairs, for both recurrent and capital expenditures. The data also include the type of revenue, including tax revenues and other internally generated revenues, and other sources of revenue for each LGA and state.

Weather data include annual rainfall and average annual temperature data, which are estimated gridded data from the Climatic Research Unit (CRU 2020) and the National Oceanic and Atmospheric Administration's Physical Sciences Laboratory (NOAA/OAR/ESRL PSL 2020), respectively. The data used cover the period from 1980 through 2015 and were extracted for the geographical coordinates of the enumeration areas reported in LSMS-ISA.

4 EMPIRICAL APPROACH

Two sets of analyses are conducted in this study. The first set examines the effects of PEA on broad development outcomes at the household level. The second set examines the effects of PEA on farm households' economic flexibility.

Effects on Broad Development Outcomes

The first set of analyses are conducted in the standard panel data setting, closely following the methodologies described in our companion paper (Takeshima, Smart, et al. 2020). Specifically, we estimate

$$y_{ijt} = \alpha + \beta_{Share} PEA_{jt}^{share} + \beta_{Size} PE_{jt} + \gamma \cdot Z_{it} + \theta_i + \varepsilon_{it}, \quad (1)$$

where y_{ijt} is various outcomes of interest for household i located in administrative unit j (LGA and/or state), at survey round t ($t = 1, 2, 3$). PEA_{jt}^{share} is the agricultural share of public expenditures by LGA or state j, and PE_{jt} is the size of public expenditures per capita in j. Z_{it} is a set of time-variant exogenous variables. θ_i is the unobserved, time-invariant household fixed effects, which may be correlated with Z_{it}. θ_i may also be correlated with E_{jt}, if θ_i is correlated at the LGA or state level (for example, farmers in certain LGAs may follow particular norms in how they conduct agricultural production activities). Using a fixed-effects model to control for θ_i therefore mitigates biases in estimated parameters β_{Share} and β_{Size}, which measure the effects of PEA-related variables on agricultural outcomes. α and γ are other estimated parameters, while ε_{it} is idiosyncratic time-variant errors.

Analytical variables y_{ijt} – outcome variables of interest

Our outcome variables of interest include consumption, the incidence of poverty, whether the household has nonfarm income, and investments in physical capital assets for households' nonfarm enterprises, as well as household dietary diversity scores.

The value of consumption (per capita) is calculated by aggregating the value of food consumption (home consumption converted into expenditure values using market prices, as well as actual eating-out expenditures), expenditures on nondurable consumption goods, education for household members, health expenditures, net purchase of livestock, net purchase of household assets, housing expenses including utilities (water, electricity, fuel, land and mobile phones, refuse disposal, and rent payments), net cash lending, net purchase of agricultural equipment, net of other unearned income, and remittances received. Consumption and expenditure figures in each category are reported in LSMS-ISA over different time periods. For this reason, we converted each component of household consumption and expenditure to its 12-month equivalent.

Poverty status is indicated by using the per capita household income described above and applying the poverty line of $3.20 per day (international dollars, adjusted for purchasing power parity [PPP]). This poverty line has been suggested as a typical poverty line for lower-middle-income countries, including Nigeria (Jolliffe and Prydz 2016), and has been recently adopted by the World Bank as a benchmark. We apply this poverty line instead of the national poverty line, as the national poverty line is more complex to define. From the data, we converted household-level expenditure values to PPP international dollars using the exchange rates in the respective years between the Nigerian naira and PPP international dollars (World Bank 2020), and as well as regional price indexes provided with the LSMS-ISA data.

Household nonfarm revenue is defined as any nonfarm household enterprise earnings, any wage income by any household members, income from savings interest, investment income, property rental income, or other income (retirement, pension, etc.). We also included wage income earned on other households' farms, although this accounts for a relatively small share of all wage incomes by household members.

Productive assets and physical capital goods in nonfarm household enterprises are also considered important indicators of households' economic potential, resilience against risk (Zimmermann and Carter 2003), and freedom from the poverty trap (McKenzie and Woodruff 2006; de Mel, McKenzie, and Woodruff 2008). These assets are measured as the sum of the imputed market values of all capital assets owned and used for the household's nonfarm enterprises.[2]

Dietary diversity has been considered an important indicator of nutrition security and overall quality of food consumption (Fan, Yosef, and Pandya-Lorch 2019; Takeshima, Akramov, et al. 2020), including for Nigeria (Amare et al. 2018; Ecker, Hatzenbuehler, and Mahrt 2018). Among others, the household dietary diversity score (HDDS) has long been used as one of the key indicators of dietary diversity. HDDSs for the post-planting and post-harvesting periods are calculated based on the seven-day recall data in LSMS-ISA, following the classification methods described in the Food and Agriculture Organization of the United Nations guidelines (FAO 2011). Note that the results should be interpreted with caution because long recall periods (for example, seven days) can sometimes lead to greater recall errors than shorter recall periods (FAO 2011, 10).

Control variables

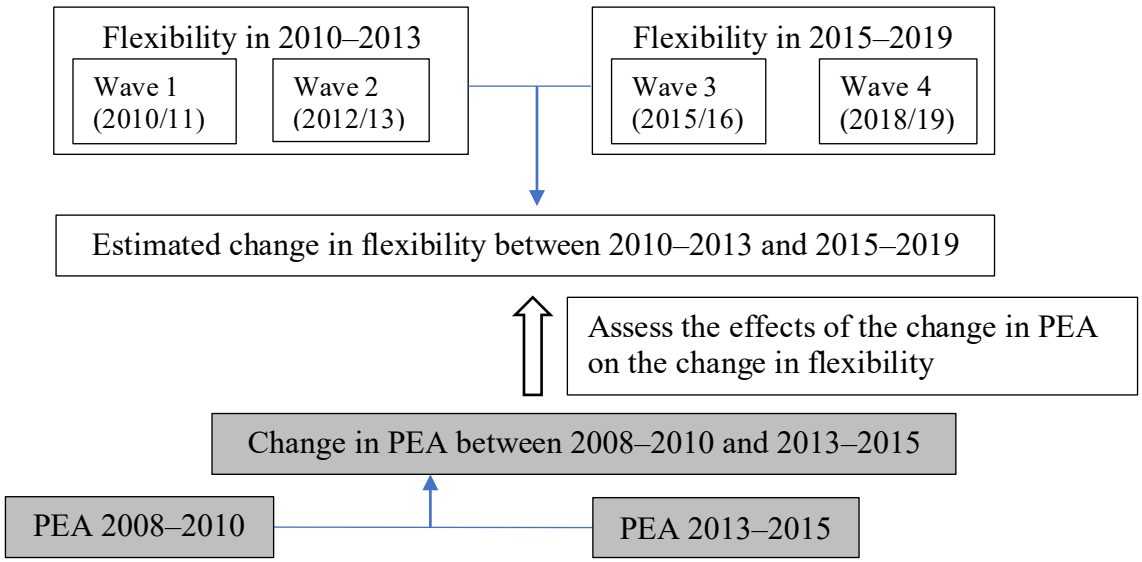
The same set of control variables used in Takeshima, Smart, et al. (2020) are used for Z_{it} in this study as well. These variables consist of (a) household demographics, (b) wealth endowments, (c) agricultural input market conditions, (d) weather conditions, (e) access to various community-level organizations or institutional infrastructure for various services (health, education, finance, etc.), and (f) community-level shocks. Details of each variable are described in Takeshima, Smart, et al. (2020) and are also shown in the descriptive statistics in the following section.

Effects on Flexibility in Shifting between Farm and Nonfarm Income-Earning Activities

The second set of analyses, estimations of the effects of PEA on flexibility, proceed in ways that slightly differ from the above specifications (Figure 4.1). In essence, using four waves of panel data, we estimate indicators of flexibility for two subperiods, the first period consisting of waves 1 and 2, and the second period consisting of waves 3 and 4. This gives us the change in flexibility between these two subperiods. We then attempt to explain the variations in the changes in flexibility by the changes in PEA between two subperiods that correspond to these two subperiods, specifically the changes in average PEA between 2008–2010 and 2013–2015. We follow this approach because the estimation of flexibility itself requires at least two rounds of panel data, and the effects of PEA on flexibility can be identified only between the two subperiods, but not between waves 1 and 2 or between waves 3 and 4. Appendix A describes in more detail the econometric specifications used to obtain the estimates.

[2] While uncommon, this may include certain capital assets that can be used for both nonfarm and farming activities, such as tractors that can be used for both land preparation and also transporting of farm/nonfarm goods.

Figure 4.1 Illustration of estimation methods (effects on flexibility)



Source: *Authors.*
Note: PEA = public expenditures on agriculture.

5 DESCRIPTIVE STATISTICS

Table 5.1 summarizes the descriptive statistics of annual public expenditures per household, calculated for the LSMS-ISA samples, including agricultural and nonagricultural households. Similar descriptive statistics are provided in Takeshima, Smart, et al. (2020), except that the figures here also include nonagricultural households. As in Takeshima, Smart, et al. (2020), figures are expressed as the equivalent values of kilograms of staple food valued at their local prices (average of rice and gari). For example, the value of recurrent expenditures on agriculture spent by the own LGA (LGAO) of the household in the year of the LSMS-ISA surveys was equivalent to 1.51 kilograms of staple food per household per year. Overall patterns are similar to those in Takeshima, Smart, et al. (2020, Table 1), except that both agricultural and total expenditures are slightly lower. Such differences are primarily due to the fact that a greater share of agricultural households are located in LGAs or states with higher agricultural and total spending per household.

Table 5.1 Descriptive statistics of public expenditure values among all households (annual value per capita, equivalent to the value of local staple food in kg)

Variables	Recurrent expenditure			Capital expenditure			Total expenditure		
	Mean	Median	Std. dev.	Mean	Median	Std. dev.	Mean	Median	Std. dev.
LGAO, year *t*, agriculture	1.51	0.51	3.15	1.26	0.01	20.26	2.78	0.69	20.75
LGAO, year *t*, total	56.94	44.57	50.23	34.53	23.55	42.19	91.47	74.08	73.08
Share	2.44	1.42	3.16	1.89	0.05	4.23	2.23	1.19	3.17
LGAO, year *t* – 1, agriculture	1.64	0.64	2.66	0.83	0.06	3.64	2.48	0.97	4.95
LGAO, year *t* – 1, total	61.94	49.68	56.62	18.29	8.68	72.37	81.23	63.99	96.44
Share	2.65	1.56	3.08	3.07	0.69	5.69	2.71	1.64	3.18
LGAO, year *t* – 2, agriculture	2.07	0.85	4.50	2.13	0.10	23.45	4.19	1.27	24.08
LGAO, year *t* – 2, total	51.06	36.96	95.72	28.07	17.63	47.83	79.13	60.55	111.44
Share	3.71	2.56	4.37	3.04	0.57	5.75	3.51	2.33	4.36
LGAN, year *t*, agriculture	1.66	0.77	2.32	1.49	0.21	11.48	3.16	1.08	11.98
LGAN, year *t*, total	62.26	55.23	35.61	37.62	28.56	31.68	99.88	88.85	52.81
Share	2.38	1.56	2.60	2.34	1.08	4.00	2.37	1.52	3.18
LGAN, year *t* – 1, agriculture	2.84	0.88	16.41	0.95	0.33	1.92	3.80	1.38	17.23
LGAN, year *t* – 1, total	67.42	58.58	48.21	28.63	12.13	44.68	96.05	75.87	134.37
Share	2.68	1.78	3.13	3.90	2.77	4.21	2.92	2.02	3.14
LGAN, year *t* – 2, agriculture	2.13	1.26	2.38	2.16	0.51	11.44	4.28	1.90	11.95
LGAN, year *t* – 2, total	54.69	46.50	62.60	29.08	23.52	25.45	83.77	74.34	70.08
Share	3.85	2.98	3.33	3.90	2.28	5.24	3.91	2.87	3.75
State, year *t*, agriculture	2.11	1.31	2.62	2.64	0.75	5.35	4.75	3.19	6.06
State, year *t*, total	75.38	64.59	59.15	57.70	44.00	68.68	133.08	111.77	116.30
Share	3.07	1.89	3.70	4.23	1.60	6.78	3.60	2.46	3.98
State, year *t* – 1, agriculture	3.04	1.61	4.66	2.18	1.14	2.98	5.22	3.52	6.39
State, year *t* – 1, total	79.53	68.52	55.48	58.68	48.61	56.75	138.21	122.60	91.86
Share	3.59	2.16	4.12	3.38	2.66	3.75	3.40	2.35	3.34
State, year *t* – 2, agriculture	2.00	0.98	3.20	3.20	0.75	7.23	5.20	2.81	8.56
State, year *t* – 2, total	61.01	48.39	45.79	55.25	39.84	63.32	116.26	100.14	84.02
Share	2.87	1.60	4.00	4.43	1.27	7.22	3.63	2.25	4.39
Sample size (three waves combined)		14,491			14,491			14,491	

Source: Authors, based on Nigeria, Federal Ministry of Finance (2015) and LSMS-ISA (NBS and World Bank 2016, 2019) data.
Note: Recurrent and capital expenditures may not add up to total expenditures due to rounding of decimals, and the total expenditures include a very small share of other categories that are neither recurrent nor capital. LGAO = local government area (own); LGAN = local government area (neighboring).

Similarly, Table 5.2 summarizes the descriptive statistics for tax revenues, internally generated revenues (which also include tax revenues), and all revenues by the LGAs and states of LSMS-ISA sample households. Figures are shown as per household per year, in values equivalent to kilograms of staple food. Tax revenues and internally generated revenues are relatively small compared to total revenues, suggesting that the majority of revenues consist of transfers from the central government. Gross expenditures by LGAs and states therefore largely account for the significant variations in direct net transfers to households in the respective LGAs and states.

Table 5.2 Descriptive statistics of government revenue values per household (annual value per household, equivalent to the value of local staple food in kg)

Administrative units and period	Categories of revenues								
	Tax revenues			Internally generated revenues			All revenues		
	Mean	Median	Std. dev.	Mean	Median	Std. dev.	Mean	Median	Std. dev.
LGAO, year *t*	0.17	0.00	0.99	1.25	0.52	2.29	72.79	67.24	36.05
LGAO, year *t* – 1	0.27	0.01	1.68	1.71	0.57	5.40	74.56	68.26	37.93
LGAO, year *t* – 2	0.19	0.00	1.42	1.15	0.43	2.60	78.25	74.23	42.61
LGAN, year *t*	0.15	0.04	0.33	1.23	0.77	1.22	78.08	74.61	29.31
LGAN, year *t* – 1	0.20	0.04	0.55	1.69	0.89	3.64	80.34	76.06	32.15
LGAN, year *t* – 2	0.16	0.03	0.45	1.23	0.68	1.83	84.66	82.92	32.31
State, year *t*	10.74	6.57	15.78	21.00	12.58	24.06	95.35	91.22	70.63
State, year *t* – 1	11.23	6.72	23.07	22.13	12.01	31.30	141.60	128.66	76.65
State, year *t* – 2	6.38	4.15	9.18	17.86	11.38	22.37	141.59	125.77	84.22

Source: Authors, based on Nigeria, Federal Ministry of Finance (2015) and LSMS-ISA (NBS and World Bank 2016, 2019) data.
Note: LGAO = local government area (own); LGAN = local government area (neighboring).

Table 5.3 summarizes the descriptive statistics (all waves combined) of nonagricultural outcome variables. Not surprisingly, most households are consumption-poor, with per capita consumption values worth approximately 350 kilograms of staple foods annually, or 1 kilogram per day. Consequently, about 35 percent and 60 percent of households fall below the poverty lines of 1.90 and 3.20 PPP international dollars per day, respectively. Most households have nonfarm income. Some households have significant nonfarm enterprise capital assets. Lastly, the average HDDS (one-week recall) is around 8 in both the post-planting period and the post-harvesting period, still well below 12, which is commonly regarded as sufficient.

Table 5.3 Descriptive statistics of key outcome variables of interest

Variables	Mean	Median	Std. dev.
Per capita consumption (value, annual equivalent)	484.907	348.933	1,019.621
Poverty at 1.90 international dollars, PPP adjusted, per day (yes = 1)	0.349	0.000	0.477
Poverty at 3.20 international dollars, PPP adjusted, per day (yes = 1)	0.599	1.000	0.490
Whether having nonfarm income source (yes = 1)	0.776	1.000	0.417
Nonfarm enterprise capital (value)	971.595	0.000	19,146.500
Household dietary diversity score (post-planting period)	7.775	8.000	2.117
Household dietary diversity score (post-harvesting period)	8.162	8.000	1.946

Source: Authors, based on LSMS-ISA data (NBS and World Bank 2016, 2019).
Note: "Value" is in equivalent to kilograms of staple food valued at local prices. PPP = purchasing power parity.

Table 5.4 summarizes the descriptive statistics of all control variables among all household samples. Not surprisingly, compared to the descriptive statistics of rural agricultural households shown in Takeshima, Smart, et al. (2020, Table 5), average household characteristics are somewhat more endowed with various resources and have better access to various community organizations and institutional infrastructure. Most households are headed by adult males, and working-age members have on average 5.6 years of education. These households are also generally asset-poor (with average and median asset values of 310 and 70 per capita, respectively) and are located close to an hour away from a district administrative center by

common means of transportation. Most households are, however, in communities with some community groups and institutional infrastructure of various types that provide public services in health, education, and other social services. Standard deviations of each variable suggest considerable heterogeneity in household characteristics.

Table 5.4 Other control variables, all waves combined (all households, including nonagricultural households)

Variables	Mean	Median	Std. dev.
Rainfall anomaly of survey year (z-score with reference period of 1980–2010)	1.04	1.02	1.52
Temperature anomaly of survey year (z-score with reference period of 1980–2010)	0.98	1.02	0.98
Age of household head	51.16	50.00	15.53
Distance to nearest administrative center (minutes)	63.94	47.90	54.82
Agricultural wages (value per day)	6.94	6.18	2.46
Average education of working-age members (years)	5.62	6.00	4.54
Gender of household head (1 = female)	0.17	0.00	0.37
Household size (male, over 60 years old)	0.20	0.00	0.40
Household size (female, over 60 years old)	0.16	0.00	0.38
Household size (male, 20–60 years old)	1.01	1.00	0.89
Household size (female, 20–60 years old)	1.24	1.00	0.91
Household size (male, 15–19 years old)	0.24	0.00	0.52
Household size (female, 15–19 years old)	0.20	0.00	0.47
Household size (male, 10–14 years old)	0.32	0.00	0.60
Household size (female, 10–14 years old)	0.27	0.00	0.54
Household size (male, 5–9 years old)	0.53	0.00	0.81
Household size (female, 5–9 years old)	0.49	0.00	0.77
Household size (male, 0–4 years old)	0.38	0.00	0.68
Household size (female, 0–4 years old)	0.35	0.00	0.65
Price of fertilizer (value per kg)	1.94	1.90	0.45
Value of livestock (value, 1,000)	1.58	0.00	10.78
Value of household assets per capita (value, 1,000)	0.31	0.07	3.58
Distance to nearest major market (minutes)	66.91	60.70	43.64
Farm size (outright purchased or community distributed) (ha)	0.40	0.00	2.18
Number of plots (outright purchased or community distributed)	1.22	1.00	1.30
Euclidean distance to nearest major urban center (geographic minutes)	4.83	1.32	20.28
Tractor owners in local government area (sample share)	0.01	0.00	0.04
Community-level negative shocks in previous year (yes = 1)			
Drought	0.04	0.00	0.20
Flood	0.16	0.00	0.36
Crop disease / pests	0.06	0.00	0.24
Livestock disease	0.03	0.00	0.18
Human epidemic disease	0.03	0.00	0.18
Sharp change in prices	0.17	0.00	0.37
Massive job layoffs	0.03	0.00	0.16
Loss of key social service(s)	0.03	0.00	0.16
Power outage(s)	0.07	0.00	0.25
Other negative shocks	0.10	0.00	0.31
Community-level positive shocks in previous year (yes = 1)			
Development project	0.10	0.00	0.30
New employment opportunity	0.02	0.00	0.15
New health facility	0.06	0.00	0.23
New road	0.08	0.00	0.28

Variables	Mean	Median	Std. dev.
New school	0.07	0.00	0.25
Improved transportation services	0.06	0.00	0.24
On-grid electricity	0.03	0.00	0.18
Off-grid electricity	0.01	0.00	0.09
Other positive shocks	0.10	0.00	0.30
Organizations in the community (yes = 1)			
Village development committee	0.60	1.00	0.49
Agricultural coop	0.23	0.00	0.42
Savings and credit coop	0.18	0.00	0.39
Business association	0.24	0.00	0.43
Women's group	0.59	1.00	0.49
Youth group	0.71	1.00	0.46
Political group	0.74	1.00	0.44
Cultural group	0.37	0.00	0.48
Health committee	0.22	0.00	0.41
School committee	0.36	0.00	0.48
Parent-teacher association	0.66	1.00	0.47
Nongovernmental organization	0.05	0.00	0.21
Community police/watch group	0.52	1.00	0.50
Disabled association	0.07	0.00	0.25
Other	0.02	0.00	0.14
Infrastructure in the community (yes = 1)			
Nursery school	0.62	1.00	0.48
Primary school	0.84	1.00	0.36
Secondary school	0.60	1.00	0.48
Health center	0.62	1.00	0.48
Public hospital	0.24	0.00	0.42
Private hospital	0.29	0.00	0.45
Private clinic	0.33	0.00	0.46
Private doctor/specialist	0.20	0.00	0.39
Midwife	0.34	0.00	0.46
Dentist	0.09	0.00	0.28
Pharmacy	0.26	0.00	0.43
Cell phone distributor	0.24	0.00	0.42
Post office	0.18	0.00	0.37
Bus/minibus stop	0.47	0.00	0.49
Internet café	0.21	0.00	0.40
Bank (formal sector)	0.18	0.00	0.38
Microfinance institution	0.17	0.00	0.37
Police station	0.38	0.00	0.48
Market	0.64	1.00	0.47
Mosque or church	0.91	1.00	0.28
Community center	0.39	0.00	0.48
Fire station	0.08	0.00	0.27

Source: Authors, based on LSMS-ISA data (NBS and World Bank 2016, 2019).
"Value" is equivalent to the value of kilogram of staple food evaluated at local market prices.

6 EMPIRICAL RESULTS

6.1 Effects on Broad Development Outcomes

Tables 6.1 and 6.2 summarize the effects of the shares and sizes of PEA on household-level development outcomes among all households and among rural agricultural households, respectively. The "share" columns show the effects of a 1 *percentage point* increase in PEA on outcome variables, while the "size" columns show the effects of a 1 *percent* increase in PEA on outcomes. For example, increasing the PEA share by 1 percentage point was found to increase household-level per capita consumption by 2.161 percent, with statistical significance at the 1 percent level, and increasing the overall size of public expenditures (holding the PEA share constant) by 1 percent further increased per capita consumption by 0.245 percent, with statistical significance at 1 percent, for all households.

Generally, the results suggest the following key patterns:

- Higher PEA *shares* had statistically significant positive effects on a number of development outcomes at the household level, including consumption, poverty reduction, nonfarm enterprise capital investments, and household dietary diversity (especially during the post-harvesting period). This holds among all households as well as rural agricultural households.
- Increasing PEA *size* is found to have somewhat more mixed effects on these outcomes, partly consistent with the potential effects of Ricardian equivalence discussed in Takeshima, Smart, et al. (2020). Certain outcomes, such as investments in nonfarm household enterprise capital, seem to respond positively to greater PEA size. In some way, households may focus more on long-term investments (such as investments in nonfarm enterprise capital) than contemporary consumption in response to greater PEA size, as the former indicates a transfer of consumption to the future rather than today, which is again consistent with the Ricardian equivalence hypothesis. While the underlying mechanisms must be examined more closely in future studies, these patterns suggest that PEA shares and sizes can affect different aspects of agricultural outcomes.
- Importantly, among all households, effects are as positive as or somewhat more positive than among rural agricultural households. These patterns generally underscore the arguments that the role of agricultural growth in inducing overall economic growth and improvement in overall livelihood is as important as its more direct role in rural development through raising agricultural incomes.
- Disaggregating the effects of PEA by LGA PEA and state PEA further suggests complex pathways of PEA impact, since different development outcomes seem to respond differently to LGA PEA and state PEA. Similarly, disaggregating the effects by recurrent and capital PEA suggests that different types of spending have effects on different aspects of agricultural outcomes. Again, future studies will need to examine more closely the effectiveness of PEA by different levels of government, as well as types of spending. However, our findings here generally underscore the importance of increasing PEA at both LGA and state levels, for recurrent as well as capital spending.

Table 6.1 Effects of PEA share and size on various development outcomes (all households)

Outcome variables	Level of aggregation of public-expenditure variables									
	Averaged over LGA and state, and aggregated over recurrent and capital expenditures		Disaggregated between LGA and state expenditures				Disaggregated between recurrent and capital expenditures			
	Share	Size	Share		Size		Share		Size	
			LGA	State	LGA	State	Recurrent	Capital	Recurrent	Capital
Consumption per capita (% change)	2.161*** (.603)	0.245*** (.050)	.801** (.397)	1.172*** (.330)	-.018 (.021)	.179*** (.040)	2.405*** (.727)	1.221*** (.313)	.258*** (.056)	.187*** (.046)
Above poverty line of 3.20 international PPP dollars per day per capita (yes = 1)	.539*** (.204)	.023* (.012)	.265* (.155)	.269* (.139)	-.002 (.008)	.002 (.010)	.177 (.097)	.459*** (.111)	.025 (.018)	-.023** (.011)
Nonfarm income (yes = 1)	.079 (.130)	.007 (.007)	.045 (.105)	.034 (.085)	-.005 (.006)	.003 (.006)	-.114 (.160)	.111† (.073)	.014 (.011)	.008 (.006)
Nonfarm capital (% change)	2.825** (1.273)	.226*** (.068)	2.000* (.908)	.864 (.856)	-.025 (.044)	.115* (.059)	2.205† (1.237)	.901† (.552)	.409*** (.078)	.060 (.053)
Household dietary diversity score (post-planting season)	3.125*** (1.220)	-.295*** (.051)	1.264† (.766)	1.987*** (.792)	-.027 (.044)	-.264*** (.050)	4.724*** (1.303)	-.197 (.522)	-.132* (.073)	-.206*** (.044)
Household dietary diversity score (post-harvesting season)	1.676* (1.015)	-.011 (.050)	.056 (.702)	1.480** (.697)	.015 (.032)	-.060 (.054)	4.792*** (1.226)	-.053 (.552)	.061 (.070)	-.031 (.046)
Sample size	14,491	144,91	14,491	14,491	14491	14,491	14,491	14,491	14,491	14,491

Source: Authors.

Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. Numbers in parentheses are standard errors. In this table, standard errors are adjusted for two-way cluster correlation, that is, within enumeration areas in each wave and within households across waves, using the `vcemway` command in Stata (Gu and Yoo 2019). "Share" indicates the effects of increasing the PEA share while fixing the total size of public expenditures. "Size" refers to the effects of increasing the size of public expenditures while fixing the PEA share. LGA = local government area; PEA = public expenditures on agriculture; PPP = purchasing power parity.

Table 5.2 Effects of PEA share and size on various development outcomes (rural agricultural households)

Outcome variables	Level of aggregation of public-expenditure variables									
	Averaged over LGA and state, and aggregated over recurrent and capital expenditures		Disaggregated between LGA and state expenditures				Disaggregated between recurrent and capital expenditures			
	Share	Size	Share		Size		Share		Size	
			LGA	State	LGA	State	Recurrent	Capital	Recurrent	Capital
Consumption per capita (% change)	1.617*** (.520)	-.079** (.032)	.732* (.391)	.847** (.357)	-.019 (.018)	-.062* (.035)	-.187 (.598)	.634** (.266)	-.050 (.044)	-.058** (.024)
Above poverty line of 3.20 international PPP dollars per day per capita (yes = 1)	.642** (.290)	-.021 (.014)	.424** (.212)	.225 (.196)	-.003 (.011)	-.039* (.022)	.135 (.356)	.416*** (.155)	-.017 (.027)	-.014 (.014)
Nonfarm income (yes = 1)	.037 (.225)	.038*** (.014)	-.027 (.194)	.039 (.143)	.004 (.010)	.016† (.010)	-.187 (.255)	.172* (.102)	.025* (.014)	.028** (.011)
Nonfarm capital (% change)	-1.731 (1.678)	.268*** (.091)	.894 (1.178)	-2.079* (1.071)	.036 (.047)	.098 (.075)	-2.517 (1.904)	-1.195 (.810)	.405*** (.117)	.018 (.075)
Household dietary diversity score (post-planting season)	7.081*** (1.654)	-.353*** (.087)	3.613*** (1.090)	3.308*** (1.058)	-.005 (.054)	-.384*** (.115)	7.256*** (1.904)	1.015 (.763)	-.218* (.119)	-.159** (.074)
Household dietary diversity score (post-harvesting season)	2.361† (1.484)	-.189** (.083)	-.139 (1.054)	1.958* (1.035)	-.016 (.045)	-.185* (.107)	4.304** (1.764)	-.517 (.778)	-.064 (.101)	-.134* (.069)
Sample size	7,763	7,763	7,763	7,763	7,763	7,763	7,763	7,763	7,763	7,763

Source: Authors.

Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. Numbers in parentheses are standard errors. In this table, standard errors are adjusted for two-way cluster correlation, that is, within enumeration areas in each wave and within households across waves, using the `vcemway` command in Stata (Gu and Yoo 2019). "Share" indicates the effects of increasing the PEA share while fixing the total size of public expenditures. "Size" refers to the effects of increasing the size of public expenditures while fixing the PEA share. LGA = local government area; PEA = public expenditures on agriculture; PPP = purchasing power parity.

Robustness

As was described above, the primary results in Tables 6.1 and 6.2 are based on PEA one and two years before each survey round. Further, these primary results also consider the potential spillover from neighboring LGAs, and LGA PEA is measured as the average PEA in the LGA of the household as well as in all contiguous LGAs.

To check the robustness of our results, we estimated the same models relaxing these assumptions (Tables B.1 through B.7 in Appendix B). In Table B.1, PEA is measured as the average over three years including the current year, instead of two years excluding the current year. In Table B.2, the same PEA measures are used for rural agricultural households. In Tables B.3 and B.4, the effects of PEA from each year (current and one year and two years before the

survey year) are separately estimated. In Tables B.5 and B.6, the same models are estimated excluding PEA by neighboring LGAs. While there are minor differences in the statistical significance, the overall patterns of these results are consistent with those from our primary results presented in Tables 6.1 and 6.2 above. Tables B.5 and B.6 also suggest that the effects of previous years' PEA are often consistently important positive drivers of nonagricultural outcomes in current years; much of the impact of PEA may therefore materialize with some time lags (for example, one or two years) and must be monitored with such a time span in mind.

Other coefficients

Our primary interest is in the effects of PEA-related variables on agricultural outcomes, and the effects of other control variables are of secondary importance. We therefore summarize the statistically significant signs in Appendix B, Table B.7. The estimated signs generally vary depending on the outcomes of interest, but most variables have statistically significant effects for at least some of the outcomes, suggesting that including them as control variables is justified.

6.2 Effects on Flexibility

Table 6.3 summarizes the effects of PEA shares on households' flexibility in shifting between farming and nonfarm activities. It shows how estimated flexibility indicators differ between samples separated by threshold levels of changes in PEA shares between waves 1–2 and waves 3–4. For example, the first row shows the case where samples were split based on whether the PEA shares decreased more, or less, than 3.0 percentage points between the 2008–2010 and 2013–2015 periods. Approximately 20 percent of sample households were in areas where PEA shares decreased by more than 3.0 percentage points. The remaining 80 percent of households, which were in areas where PEA shares decreased less (or relatively increased), experienced a net increase of 2.208 in the flexibility indicator (with statistical significance at 10 percent), compared to the 20 percent of households that experienced a relative decrease in PEA share (below the 20th percentile) during the same period. These results hold consistently for a range of thresholds (up to a 1.5 percentage point decrease in PEA shares), although they are less significant when more positive (less negative) thresholds are considered. These results are consistent with the hypothesis that increasing the PEA share has helped households retain flexibility in shifting between farming and nonfarm activities. Furthermore, the results suggest that such patterns are particularly strong in the North region of the country (North Central, North East, and North West zones), where agriculture is a particularly important source of livelihood.

Table 6.3 Effects of PEA shares on flexibility indicator

Threshold value of PEA share change between 2008–2010 and 2013–2015 (percentage point)	Share of sample below threshold PEA change	Effects of increased PEA share on flexibility index		
		All sample	North	South
-3.0	20%	2.208* (1.353)	3.055* (1.671)	Insignificant
-2.5	25%	2.344* (1.211)	3.311** (1.577)	Insignificant
-2.2	30%	1.806* (1.051)	2.866** (1.471)	Insignificant
-2.0	33.3%	1.778* (1.043)	2.828* (1.505)	Insignificant
-1.5	40%	1.815* (1.016)	2.992** (1.526)	Insignificant
-1.1	50%	Insignificant	Insignificant	Insignificant
-0.4	60%	Insignificant	Insignificant	Insignificant
-0.1	66.7%	Insignificant	Insignificant	Insignificant
0.0	70%	Insignificant	Insignificant	Insignificant
0.2	75%	Insignificant	Insignificant	Insignificant
0.8	80%	Insignificant	Insignificant	Insignificant

Source: Authors.
Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. PEA = public expenditures on agriculture.

As was described briefly above, greater flexibility to shift between nonfarm activities and farming activities can be particularly important during social shocks like today's COVID-19 crisis. Because of disruptions in food markets and restrictions on worker mobility (especially in rural-to-urban migration) that can emerge as a result of government response measures against COVID-19, some farm households might find themselves suddenly being forced to switch a significant share of their economic activities from nonfarm activities to farming activities (including subsistence production of certain food crops). Households with greater flexibility are more resilient against this type of shock, as they can switch between nonfarm activities and farming activities without facing a significant increase in production costs. Our findings suggest that greater PEA shares have helped farm households increase this flexibility and be more prepared for shocks like COVID-19.

7 CONCLUSIONS

Agricultural development has long been considered an important driver of overall economic development. Conventional literature has provided theoretical arguments for such linkages, and recent literature has continued to provide empirical support for these linkages. However, direct evidence of the impact of policy variables such as PEA on these outcomes at the household level is thin in developing countries such as Nigeria. In addition, there has been growing interest in resilience, which can be measured in various ways, including via indicators such as flexibility, and resilience is also relevant in today's rapidly changing socioeconomic environment due to shocks such as COVID-19. The direct evidence of PEA impact on broad development outcomes is also important in informing regional initiatives (such as those advocated and supported by CAADP) aiming to use PEA as an instrument for overall food security enhancement and poverty reduction in Africa. This study aimed to provide initial evidence at the household level, using data from Nigeria.

The findings have important implications. The findings generally suggest that greater PEA shares have positive effects on various development outcomes at the household level, including consumption, poverty reduction, nonfarm capital investments, and household dietary diversity. These findings are consistent with the hypotheses of positive linkages between PEA

and agricultural outcomes, and linkages between agricultural and nonagricultural outcomes, often advocated in the literature. The findings also suggest that a greater PEA share is likely to help farm households enhance their economic flexibility in switching between nonfarm and farming activities, thus potentially increasing their resilience against shocks, including those associated with COVID-19. These findings underscore the importance of efforts to reallocate more public expenditures toward agriculture in countries such as Nigeria, as a policy instrument to achieve not only agricultural growth but also overall economic growth, welfare improvement, and food- and nutrition-security improvements.

The findings also suggest, however, that, similar to the findings on agricultural outcomes presented in Takeshima, Smart, et al. (2020), PEA should be increased by increasing its *share* of public expenditures through conscious efforts to reallocate existing resources, rather than trying to increase PEA by increasing the overall *size* of public expenditures. Our findings suggest that, oftentimes, increasing PEA by increasing overall public expenditures (while maintaining the PEA share) has less effect. Such patterns are in one way consistent with the Ricardian equivalence theory, which holds that the general public associates public expenditure increases today with future increases in tax payments, thus offsetting the effects of the public expenditure increases.

Lastly, again similar to Takeshima, Smart, et al. (2020), findings in this study also suggest that it is more important to continue identifying the specific source (for example, LGA or state) and type of spending (for example, recurrent or capital) that can be most effective for specific development outcomes, rather than seeking a one-size-fits-all approach. These findings again imply the importance of enhancing research capacity to investigate the impact pathways of PEA on overall livelihood improvement.

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Appendix A: Econometric Models for the Estimation of the Effects of Public Expenditure on Agriculture (PEA) on Households' Flexibility in Shifting between Farm and Nonfarm Activities

The approach illustrated in Figure 4.1 in the main text is operationalized in the following way. First, we estimate the parametric approximation of the input distance function (IDF). IDF has been used in the production economics literature, partly to extract the key features of production technologies such as economies of diversification (Coelli and Perelman 1996; Coelli and Fleming 2004; Irz and Thirtle 2004; Nguyen 2017) and flexibility (Renner, Gauben, and Hockmann 2014). Specifically, we estimate

$$\begin{aligned} -\ln x_{0,ijt} \;=\; & \alpha_0 + \sum_{m=1}^{2} \alpha_m \ln y_{m,\,ijt} + \sum_{n=1}^{N} \alpha_n \ln x^*_{n,\,ijt} \\ & + 0.5 \sum_{m=1}^{2} \sum_{\ell=1}^{2} \alpha_{\ell m} \ln y_{m,ijt} \ln y_{\ell,ijt} \\ & + 0.5 \sum_{n=1}^{N} \sum_{p=1}^{N} \alpha_{np} \ln x^*_{n,ijt} \ln x^*_{p,ijt} \\ & + \sum_{n=1}^{N} \sum_{m=1}^{2} \alpha_{nj} \ln x^*_{n,ijt} \ln y_{m,ijt} + \alpha_0^E E_{jT} \\ & + \sum_{m=1}^{2} \alpha_m^E \left(\ln y_{m,\,ijt} \cdot E_{jT}\right) + \sum_{n=1}^{N} \alpha_n^E \left(\ln x^*_{n,\,ijt} \cdot E_{jT}\right) \\ & + 0.5 \sum_{m=1}^{2} \sum_{\ell=1}^{2} \alpha_{\ell m}^E \left(\ln y_{m,ijt} \ln y_{\ell,ijt} \cdot E_{jT}\right) \\ & + 0.5 \sum_{n=1}^{N} \sum_{p=1}^{N} \alpha_{np}^E \left(\ln x^*_{n,ijt} \ln x^*_{p,ijt} \cdot E_{jT}\right) \\ & + \sum_{n=1}^{N} \sum_{m=1}^{2} \alpha_{nm}^E \left(\ln x^*_{n,ijt} \ln y_{m,ijt} \cdot E_{jT}\right) + \beta_Z \cdot Z_{ijt} + \theta_{\mathrm{i}} \\ & + \theta_{\mathrm{i}}^{\mathrm{w1w2}} + \theta_{\mathrm{i}}^{\mathrm{w3w4}} + v_{it} - u_{it}, \end{aligned} \tag{2}$$

in which $x_{0,ijt}$ is the *total* amount of reference input (household labor in person-days) used for farm and nonfarm-activities of household i (in LGA or state j in survey wave t) during the previous 12 months; $x^*_{n,\,ijt} = x_{\mathrm{n},ijt} / x_{0,ijt}$ in which $x_{\mathrm{n},ijt}$ is the *total* value of other variable inputs type n (including hired labor) used for farm and nonfarm activities; and $y_{m,\,ijt}$ is the value of production of farm and nonfarm activities ($m = 1$ and $m = 2$, respectively). Z_{ijt} is other time-variant household characteristics. Symbols ℓ and p are aliases for m and n, respectively.[3]

E_{jT} is the same PEA variable used in equation (1) in the main text, except that the subscript is jT instead of jt. Specifically, as is shown in Figure 4.1, for waves 1 and 2, E_{jT} is the average of PEA between 2008 and 2010 (the year of wave 1), while for waves 3 and 4, E_{jT} is the average of PEA between 2013 and 2015 (the year of wave 3). In other words, in (2), we are interested in the effects of PEA between 2008 and 2010 (2013 and 2015) on the characteristics of households during waves 1 and 2 (waves 3 and 4). Such specifications assume that the effects of PEA on characteristics such as flexibility arise more in the medium term. This is because

[3] One of our primary analyses combines all variable inputs other than household labor into one input variable. In this case, $N = 1$.

production characteristics such as flexibility depend on economies of scale and economies of scope, which are more medium-term, rather than short-term, concepts (for example, Basu 2008).

Equation (2) is an expanded version of a standard IDF. Equation (2) is expanded by the interaction terms with PEA variable E_{jt}, which capture heterogeneity in various parameters α's as functions of E_{jt}. Recent studies such as Takeshima, Hatzenbuehler, and Edeh (2020) apply similar expansion to an IDF.

Notations α's, β's are estimated parameters. As is defined in the aforementioned literature on IDFs, the residual terms are defined as $v_{it} \sim i.i.d\ N(0, \sigma_v^2)$ and $u_{it} \sim i.i.d\ |N(0, \sigma_u^2)|$.

In (2), the additional subperiod-specific unobserved household fixed effects θ_i^{w1w2} and θ_i^{w3w4} control for the potential short-term changes in these household fixed effects between waves 1–2 (2010–2013) and waves 3–4 (2015–2019). These θ_i^{w1w2} and θ_i^{w3w4} can also affect the changes in production behaviors of the household, aside from the change in flexibility, between these subperiods. By controlling for θ_i^{w1w2} and θ_i^{w3w4}, we can more accurately capture the changes in flexibility. These short-term fluctuations in household fixed effects might occur, for example, due to short-term changes in farming ability (which can be positive if households gain some new short-term skills or experience household-specific positive shocks, or can be negative if the household faces new challenges due to location-specific pest outbreaks, etc.), which might differ from longer-term effects θ_i. In practice, θ_i^{w1w2} and θ_i^{w3w4} are controlled for, by first converting variables through within transformations in each subperiod, so that in (2),

$$\begin{array}{llll} y_{it} = y_{it} - \bar{y}_{i,12}, & x_{it} = x_{it} - \bar{x}_{i,12}, & z_{it} = z_{it} - \bar{z}_{i,12}, & t = 1,2 \\ y_{it} = y_{it} - \bar{y}_{i,34}, & x_{it} = x_{it} - \bar{x}_{i,34}, & z_{it} = z_{it} - \bar{z}_{i,34}, & t = 3,4, \end{array} \quad (3)$$

where $\bar{y}_{i,12}$, $\bar{x}_{i,12}$, $\bar{z}_{i,12}$ are averages within each household *i* over waves 1 and 2, and $\bar{y}_{i,34}$, $\bar{x}_{i,34}$, $\bar{z}_{i,34}$ are similar averages over waves 3 and 4.

We then estimate a standard panel fixed-effects model using these subperiod-within-transformed variables, by which we also control for θ_i.

Following Renner, Glauben, and Hockmann (2014), using the estimated vectors and matrixes of parameters from (2), the flexibility index can be computed as

$$\text{Flexibility} = -\left\{(\mathbf{1_I'} \cdot \mathbf{D_x})^{-1} \cdot \mathbf{y'}\left[\mathbf{D_y D'}_{\mathbf{y}} - \mathbf{D_{yy}} + \mathbf{D_{yx}}(\mathbf{D_{xx}} + \mathbf{D_x D_x'})^{-1}\mathbf{D_{xy}}\right]\boldsymbol{y} + 2(\mathbf{1_I'} \cdot \mathbf{D_x})^{-1}\left(\mathbf{1} + \mathbf{y'D_y} \cdot \mathbf{D^{-1}}\right)\right\}. \quad (4)$$

Notations are as defined in Renner, Glauben, and Hockmann (2014). In our case of two outputs and two inputs, specifically, $\mathbf{1_I}$ is the $(\mathbf{1} \times \mathbf{1})$ vector of one, and $\mathbf{D_x}$ and $\mathbf{D_y}$ are vectors of coefficients for $\ln x$ and $\ln y$ in (2). Similarly, $\mathbf{D_{yy}}$, $\mathbf{D_{xx}}$, $\mathbf{D_{xy}}$ are matrixes of coefficients for $\ln y \cdot \ln y$, $\ln x \cdot \ln x$, and $\ln x \cdot \ln y$ in (2); y is the vector of the values of outputs; and $\mathbf{D}$ is the predicted value of distance from the technology frontier estimated in (2). Formula (4) computes the flexibility index for each observation *i*, for each of two subperiods (waves 1–2 and waves 3–4). The negative sign "–" is added in front so that a more positive value of *Flexibility* indicates greater flexibility.[4] We then assess how the changes in this flexibility are affected by the changes in the corresponding PEA of the household's LGA and state.

Analytical variables

[4] This is because *flexibility* in Renner, Glauben, and Hockmann (2014) is based on the *flatness* of the cost curve, while the term inside { } in (2) measures the steepness of the curvature of the cost curve.

Output variables *y,* households' farm revenue and nonfarm revenue, are defined in Takeshima, Smart, et al. (2020) and above in this study, respectively. Both are the aggregated sum of production values of various commodities (imputed values based on local prices if home-consumed goods) that fall under the farm sector (temporary and permanent crops, livestock and fishery, and byproducts) and nonfarm sectors (nonfarm household enterprises as well as nonfarm wage earnings).

The values of other variable inputs ($x_{\mathrm{n},ijt}$) are computed in the following way. For farm activities, these include the (imputed) costs of seeds, agrochemicals, chemical fertilizer, hired labor, rental of draft animals, and hiring of agricultural machines. The costs also include livestock-related costs (hired labor including for herding, feed and its transport, veterinary service including vaccines and medicines, maintenance of pens and stables, commissions on animal sales, compensation for damage by animals, and other related costs).

For nonfarm activities, variable costs include those for nonfarm household enterprises, such as hired labor (salaries and wages), purchase of goods for sale, transport, fuel, generator maintenance, insurance, rent, interest, raw materials, and other costs. For nonfarm wage-earning activities, variable costs are assumed minimal and not included (labor input for wage-earning activities is captured in $x_{0,ijt}$).

Appendix B: Detailed Results and Signs of Statistically Significant Coefficients in the Primary Specifications

Table B.1 Effects of PEA share and size on household-level development outcomes when expenditure figures are averaged over three years including the survey year *t* (instead of two-year averages over *t* – 1 and *t* – 2 only) (all households)

Outcome variables	Level of aggregation of public-expenditure variables									
	Averaged over LGA and state, and aggregated over recurrent and capital expenditures		Disaggregated between LGA and state expenditures				Disaggregated between recurrent and capital expenditures			
	Share	Size	Share		Size		Share		Size	
			LGA	State	LGA	State	Recurrent	Capital	Recurrent	Capital
Consumption per capita (% change)	2.432***	.468***	.154	2.001***	-.017	.362***	3.547***	1.537***	.421***	.267***
Above poverty line of 3.20 international PPP dollars per day per capita (yes = 1)	-.042	.045**	-.245	.201	-.004	.008	-.054	.309**	.044**	.029*
Nonfarm income (yes = 1)	-.413**	.007	-.246*	-.179	.011	-.002	-.158	.001	.029**	.003
Nonfarm capital (% change)	4.294**	.484***	2.193*	1.966*	.069	.292***	4.718***	1.506*	.548***	.247***
Household dietary diversity score (post-planting season)	3.275*	-.309***	.587	2.312**	-.080	-.382***	6.532***	-2.070**	-.057	-.157**
Household dietary diversity score (post-harvesting season)	3.937***	.046	.411	3.207***	-.058	.029	3.791***	.681	-.162*	.182***

Source: Authors.

Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. "Share" indicates the effects of increasing the PEA share while fixing the total size of public expenditures. "Size" refers to the effects of increasing the size of public expenditures while fixing the PEA share. LGA = local government area; PEA = public expenditures on agriculture; PPP = purchasing power parity.

Table B.2 Effects of PEA share and size on household-level development outcomes when expenditure figures are averaged over three years including the survey year *t* (instead of two-year averages over *t* – 1 and *t* – 2 only) (rural agricultural households)

Outcome variables	Level of aggregation of public-expenditure variables									
	Averaged over LGA and state, and aggregated over recurrent and capital expenditures		Disaggregated between LGA and state expenditures				Disaggregated between recurrent and capital expenditures			
	Share	Size	Share		Size		Share		Size	
			LGA	State	LGA	State	Recurrent	Capital	Recurrent	Capital
Consumption per capita (% change)	2.408***	.462***	-.044	2.100***	-.011	.437***	2.244**	1.568***	.300***	.218**
Above poverty line of 3.20 international PPP dollars per day per capita (yes = 1)	-.028	.019	-.281	.120	-.006	.014	-.285	.335*	.008	.020
Nonfarm income (yes = 1)	-.933***	.039**	-.604**	-.403**	.038**	.010	-.615**	-.016	.035*	.021*
Nonfarm capital (% change)	1.655	.692***	2.049	.207	.221**	.395***	1.677	.408	.594***	.258**
Household dietary diversity score (post-planting season)	5.933**	-.314**	2.295*	2.703*	-.052	-.461***	7.646***	-1.303	-.170	-.089
Household dietary diversity score (post-harvesting season)	5.468***	-.119	.311	4.077***	-.188**	.033	4.342**	.924	-.349***	.168*

Source: Authors.

Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. "Share" indicates the effects of increasing the PEA share while fixing the total size of public expenditures. "Size" refers to the effects of increasing the size of public expenditures while fixing the PEA share. LGA = local government area; PEA = public expenditures on agriculture; PPP = purchasing power parity.

Table B.3 Effects of PEA share and size on household-level development outcomes, estimated separately for expenditures from each of the three years *t*, *t* – 1, and *t* – 2 (all households)

Outcome variables	Share			Size		
	Current year	1 year before	2 years before	Current year	1 year before	2 years before
Consumption per capita (% change)	1.023†	1.109**	2.323***	-.019	-.019	.002
Above poverty line of 3.20 international PPP dollars per day per capita (yes = 1)	-.153	-.188	.460**	-.014†	-.001	.001
Nonfarm income (yes = 1)	-.187	.019	.001	.011**	-.009	.002
Nonfarm capital (% change)	2.352*	2.786**	3.958***	.040	-.050	.022
Household dietary diversity score (post-planting season)	.078	1.882	.502	.064†	.007	-.057**
Household dietary diversity score (post-harvesting season)	.720	2.794**	-.874	-.161***	.095***	-.051**

Source: Authors.

Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. "Share" indicates the effects of increasing the PEA share while fixing the total size of public expenditures. "Size" refers to the effects of increasing the size of public expenditures while fixing the PEA share. LGA = local government area; PEA = public expenditures on agriculture; PPP = purchasing power parity.

Table B.4 Effects of PEA share and size on household-level development outcomes, estimated separately for expenditures from each of the three years *t*, *t* – 1, and *t* – 2 (rural agricultural households)

Outcome variables	Share			Size		
	Current year	1 year before	2 years before	Current year	1 year before	2 years before
Consumption per capita (% change)	.507	.504	2.036***	-.017	-.032	.013
Above poverty line of 3.20 international PPP dollars per day per capita (yes = 1)	-.159	-.244	.201	-.016	-.010	.010*
Nonfarm income (yes = 1)	-.586**	-.158	-.112	.022**	-.008	.009*
Nonfarm capital (% change)	2.348	.351	3.287*	.012	-.001	.011
Household dietary diversity score (post-planting season)	.761	2.978*	1.733	-.046	.035	-.011
Household dietary diversity score (post-harvesting season)	1.830	3.163*	-1.133	-.232***	.037	-.028

Source: Authors.

Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. "Share" indicates the effects of increasing the PEA share while fixing the total size of public expenditures. "Size" refers to the effects of increasing the size of public expenditures while fixing the PEA share. LGA = local government area; PEA = public expenditures on agriculture; PPP = purchasing power parity.

Table B.5 Effects of PEA share and size on household-level agricultural outcomes when expenditure figures from neighboring LGAs are excluded (all households)

Outcome variables	Level of aggregation of public-expenditure variables									
	Averaged over LGA and state, and aggregated over recurrent and capital expenditures		Disaggregated between LGA and state expenditures				Disaggregated between recurrent and capital expenditures			
	Share	Size	Share		Size		Share		Size	
			LGA	State	LGA	State	Recurrent	Capital	Recurrent	Capital
Consumption per capita (% change)	.634*	.244***	-.084	1.264***	-.074**	.284***	1.003*	.170	.203***	.151***
Above poverty line of 3.20 international PPP dollars per day per capita (yes = 1)	.326*	.022*	.120	.231*	-.021	.026*	.025	.181*	.023	.017*
Nonfarm income (yes = 1)	-.020	.007	-.020	.010	.006	-.004	-.265*	.062	.007	.004
Nonfarm capital (% change)	.776	.225***	.527	.837	-.007	.337***	.653	-.249	.296***	.037
Household dietary diversity score (post-planting season)	2.352**	-.297***	.720	1.387*	-.014	-.205***	4.778***	-.476	-.116*	-.158***
Household dietary diversity score (post-harvesting season)	1.319	-.013	.004	1.693**	-.068	.143**	4.681***	-.662	.098	-.050

Source: Authors.

Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. "Share" indicates the effects of increasing the PEA share while fixing the total size of public expenditures. "Size" refers to the effects of increasing the size of public expenditures while fixing the PEA share. LGA = local government area; PEA = public expenditures on agriculture; PPP = purchasing power parity.

Table B.6 Effects of PEA share and size on household-level agricultural outcomes when expenditure figures from neighboring LGAs are excluded (rural agricultural households)

Outcome variables	Level of aggregation of public-expenditure variables									
	Averaged over LGA and state, and aggregated over recurrent and capital expenditures		Disaggregated between LGA and state expenditures				Disaggregated between recurrent and capital expenditures			
	Share	Size	Share		Size		Share		Size	
			LGA	State	LGA	State	Recurrent	Capital	Recurrent	Capital
Consumption per capita (% change)	.808*	.280***	-.128	1.648***	-.103**	.334***	.317	.165	.142**	.095**
Above poverty line of 1.90 international PPP dollars per day per capita (yes = 1)	.715**	-.002	.140	.689***	-.049**	.055**				
Above poverty line of 3.20 international PPP dollars per day per capita (yes = 1)	.338	.008	.129	.294*	-.049**	.057**	.036	.106	.007	.010
Nonfarm income (yes = 1)	.068	.041**	.049	.060	.033**	.006	-.406*	.161*	.010	.017*
Nonfarm capital (% change)	-1.123	.542***	.537	-.907	.120	.386***	-1.896	-1.008	.364***	.101*
Household dietary diversity score (post-planting season)	3.983***	-.304***	1.755**	1.458	-.137	-.284**	6.428***	-.196	-.149	-.065
Household dietary diversity score (post-harvesting season)	1.541†	-.176*	-.429	2.138**	-.297***	.107	4.927***	-1.076*	.008	-.096*

Source: Authors.

Note: Asterisks indicate statistical significance: *** 1%, ** 5%, * 10%, † 15%. "Share" indicates the effects of increasing the PEA share while fixing the total size of public expenditures. "Size" refers to the effects of increasing the size of public expenditures while fixing the PEA share. LGA = local government area; PEA = public expenditures on agriculture; PPP = purchasing power parity.

Table B.7 Signs of statistically significant coefficients in the primary specifications

Variables	Consumption	No Poverty	Nonfarm income	Nonfarm capital	Dietary diversity (post-planting)	Dietary diversity (post-harvest)
Rainfall anomaly	+	–		–	+	+
Temperature anomaly		+		–	–	–
Age	–					
Distance to administrative center			–			
Agricultural wages		–	–		+	
Education	+	–	+	+	+	+
Gender of household head	+					–
Household size (male, over 60 years old)	+	+				
Household size (female, over 60 years old)		+		+	+	+
Household size (male, 20–60 years old)		+	+	+	+	–
Household size (female, 20–60 years old)	–	+	+	+	+	+
Household size (male, 15–19 years old)		+	+	+		–
Household size (female, 15–19 years old)	–	+	+	+	+	+
Household size (male, 10–14 years old)		+	+			
Household size (female, 10–14 years old)	–	+	+		+	+
Household size (male, 5–9 years old)	–	+	+	+		
Household size (female, 5–9 years old)	–	+		+	+	+
Household size (male, 0–4 years old)	–	+	+	+	+	+
Household size (female, 0–4 years old)	–	+		+		
Price of fertilizer			–	–		+
Value of livestock	+				+	
Household assets per capita	+	–	+	+	+	+
Distance to nearest major market			–	–		
Farm size			–			+
Number of plots	+	–			+	
Distance to nearest urban center						
Tractor owners in LGA	–	+				
Community-level shocks						
Drought	+				–	
Flood	+	–				
Crop disease / pests		–	–			
Livestock disease					–	
Human epidemic disease	–	+				–
Sharp change in prices		–			+	+
Massive job layoffs	–	+	–			–
Loss of key social service(s)	+					
Power outage(s)						
Other negative shocks		–				
Development project						+
New employment opportunity						
New health facility						
New road						+
New school					+	+
Improved transportation services	+					–
On-grid electricity					+	
Off-grid electricity	+	–		–		
Other positive shocks					–	+
Organizations in the community						
Village development committee					–	–
Agricultural coop	+		+		+	
Savings and credit coop				+	–	

Variables	Consumption	No Poverty	Nonfarm income	Nonfarm capital	Dietary diversity (post-planting)	Dietary diversity (post-harvest)
Business association				–		
Women's group	+					–
Youth group		+				
Political group				+		
Cultural group		+			+	
Health committee	–	+				
School committee					–	
Parent-teacher association	+		–			+
Nongovernmental organization		–				
Community police/watch group	+				–	+
Disabled association						–
Other		–				–
Number of institutions in community					+	+
Wave dummy	Included	Included	Included	Included	Included	Included
Wave × distance to urban center	Included	Included	Included	Included	Included	Included
Wave × geopolitical zone	Included	Included	Included	Included	Included	Included
Wave × tractors owners in LGA	Included	Included	Included	Included	Included	Included
Intercept	Included	Included	Included	Included	Included	Included
Sample size	14,491	14,491	14,491	14,491	14,491	14,491

Source: Authors.

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