A Cross Sectional Analysis of Farm-Size Productivity Relationship in African Agriculture

Evidence from Maize Farming Households in Nigeria

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Abstract

This paper examines the farm size and productivity relationship using data from Nigeria. The household data used has been drawn from a baseline survey conducted in Nigeria and financed by the Bill and Melinda Gates Foundations (BMGF).The relationship between farm size and productivity has long been a topic of debate in development economics. Using a cross sectional baseline data, we aimed at examining the relationship between maize yield and farm size across the selected agro-ecological zones. Specifically, it aimed at investigating the farm size–productivity relationship and its underlying determinants for maize producers in Nigeria. Findings from this study indicate that productivity measures are consistently highest among farms small farms, next highest among medium, and lowest among large farms. Gross profit per hectare and net profit per hectare on small farms are over 15% higher and 40% respectively higher than medium and large farms. The study further reveal a strong negative relationship between the value of output per hectare and own cultivated area with a doubling in cultivated area associated with a 35% or 98% decrease in the value of crop output per unit of cultivated land at the holding- or plot-level, respectively. We therefore recommended that farm size–productivity relationship and its determinants in developing countries like Nigeria should continue to be of interest to policy makers seeking to resolve the small-sized farm issue.

Keywords: Cross sectional analysis, farm size, productivity, inverse relationship, maize farming households

1. Introduction

Farm-size and productivity relationship is an age long phenomenon which has attracted several and un-concluded attentions within the agricultural economics field. One of the recurrent debates in phenomenon, apart from the causes of this relationship, is the inverse relationship (IR) between the size of a farm's operated area and its productivity. Following the perception of "small is beautiful" initially argued by Chayanov (Cha_ianov 1986) which suggests that small farms are more productive compared to large farms, an inversed farm size–productivity relationship has been widely identified in developing countries including some sub-Sharan African countries (Barrett, Bellemare, and Hou, 2010; Carletto, Savastano, and Zezza, 2013; Larson *et al*., 2014; Desiere and Jolliffe, 2018).

The two most popular explanations is to either focus on a failure to accurately measure key factors like land quality and area or inappropriate use of certain amounts of inputs by smallholder farmers, possibly due to imperfections in key factor markets such as those for labor, land, and insurance. Previous studies have shown that such a relationship tend to disappear when farm size increases, improve technologies and modernization through the adoption of more capital intensive technology. Such transformations are likely to pay more attention on other inputs rather than farm labour. With the believe that small-scale farms constitute the vast majority of farms in Africa, agricultural economists have for decades generally accepted that a smallholder-led strategy also holds the best prospects for agricultural development in Africa (Mellor, 1995; Lipton, 2006; Hazell et al., 2007). Most of these studies use data in which the vast majority of observations are less than five hectares. However, current studies have contested the viability of a smallholder-led growth strategy particularly in Africa (e.g., Collier and Dercon, 2014; Dercon and Gollin, 2014). Some parts of Sub-Saharan Africa (like Nigeria) are witnessing rapid changes in distributions of farm size with medium-scale farmers holding more than five hectares. This new trend has now accounted for a substantial growth in the share of African farmland (Jayne *et al*., 2016; African Development Bank, 2017).

Previous studies on farm size-productivity relationship have all explored the use of panel data because of its importance in analysing policy significant issues as well as providing time-series which helps to assess trends by resolving the issue of ambiguity in correlation and, more importantly, confidently demonstrate the direction of causality (Davies, 1994: Hsiao, 2014).

Despite these numerous studies, consensus and convergence on farm size and productivity relationship in African countries remained elusive (Muyanga & Jayne, 2019). Consequently, there is to explore more rigorous options to arrive at a comprehensive view of the IR phenomenon particularly in African agriculture (Bhattacharya & Saini, 1972).

One of the major contributions of this study is that it provides cross sectional (with panel component carefully integrated in the survey) analysis of the farm size-productivity relationship which could help to reduce the chances of sampling errors that are normally associated with panel survey if the subsequent waves are not representative of the population or subject to a high level of coverage errors, which are likely to accumulate over time (Deaton *et al*., 1986). Perhaps the combination of the findings from the 'specific point in time' analysis with the panel data studies could help to better understand farm size-productivity relationship in African countries including Nigeria. With the recent re-emergence of interest to diversify from oil driven economy to agriculture in Nigeria, the use resources efficiently of the small farm households is particularly relevant to make the transition from a subsistence-based to a market-driven rural economy. Therefore, re-examining the determinants of agricultural production and IR hypothesis in Nigeria based on data considered statistically representative of smallholder farms (Carletto, Savastano, and Zezza, 2013; Larson *et al*., 2013) will be of utmost importance for policy experts to establish current levels of agricultural outcomes and development indicators upon which future investment in agriculture can be based.

The remaining sections of this paper are organized as follows. Section 2 discusses the conceptual framework for a systematic relationship between farm size and productivity, the empirical evidence in support of the IR hypothesis. Methodology (data and descriptive evidence at the household and plot levels) is presented at section 3. Section 4 presents the results and discussion on the findings of production functions and regressions analysis to explain the variations between gross output and profits with respect to farm size under different assumptions regarding labor market functioning. Conclusions and implications of this study for policy and research are drawn out in section 5.

2. Conceptual framework

To provide a framework for this paper, we attempt the conceptual discussion, empirical evidence, and the farm-size-productivity relationship trend over years. The two major focus of our discussion were the unobserved land quality differentials and labor market imperfections that make small producers either apply more effort than larger producers or more than the optimum amount of family labor.

2.1 Evolution of the farm size-productivity relationship over time

A negative relationship between farm size and output per hectare was first noted in Russia (Chayanov, 1926) and in Indian farm management studies (Bardhan, 1973; Sen, 1975; Srinivasan, 1972). This relationship has been confirmed empirically and frequently perceived as a stylized fact in the literature (Eastwood *et al*., 2010; Lipton, 2009). Many studies find agricultural production to be characterized by constant economies of scale. As against the profit argument, owner-operators will more often exert more impact than wage workers who require supervision which is costly (Frisvold, 1994). Knowledge of local soil and climatic conditions of the Owner operators' often accumulated over generations. This also gives them an edge over wage workers (Rosenzweig and Wolpin, 1985).

With constant returns to scale and well-functioning factor markets or imperfections in one market only, output and intensity of input use will be identical across farm sizes. Imperfections in more than one factor markets will lead to a systematic relationship between the size of cultivated area, inputs, and yields (Feder, 1985). Small farmers' advantages in labor supervision, knowledge, and organizational advantages can be offset by their difficulty in accessing capital and insurance which arises from the high transaction cost of providing formal credit in rural markets, possibly exacerbated by the difficulty of using small farmers' assets as collateral. Frictions in labor market participation and land markets, e.g., due to transaction costs, could motivate small farmers who are unable to rent additional land to rationally apply family labor to cultivate their fixed land endowment more intensively than they would with perfect markets.

An inverse relationship can also emerge if labor and credit markets imperfections are combined with a fixed cost element for production (Eswaran and Kotwal, 1986) or if there is heterogeneity in farmers' skills in the presence of credit market imperfections (Assuncao and Ghatak, 2003). Land and insurance market imperfections can prompt small farmers who are net buyers of food to use family labor more intensively in an attempt to reduce potentially adverse effects of price fluctuations (Barrett, 1996). The lumpiness of certain inputs (e.g., machinery, draft animals and management skills) plus advantages in getting access to working capital or their capacity to diffuse risk may in practice lead the relationship between farm size and productivity to be U-shaped (Heltberg, 1998). Thus, with few exceptions, agricultural production in practice thus relies on owner-operated firms (Allen and Lueck, 1998; Deininger and Feder, 2001).

Empirically, it has long been noted that part of the reason for cross sectional evidence supporting an inverse farm size-productivity relationship (Berry and Cline, 1979; Cornia, 1985) is likely to have been the failure to fully capture land quality (Bhalla and Roy, 1988; Chen *et al*., 2011). However, this relationship appears to be robust to inclusion of broad soil quality measures in cross-sectional estimates, more sophisticated panel data estimation techniques (Assuncao and Braido, 2007; Benjamin, 1995), and inclusion of a wide array of soil characteristics such as pH, carbon, clay, and sand content (Barrett *et al*., 2010). Measurement error for land size may also explain part of the relationship (Lamb 2003), and use of GPS, though not without challenges, suggests that indeed farmers' area estimates may be biased (Carletto *et al*., 2011). It has also been argued that a proper measure of efficiency should be based on profits rather than gross output (Binswanger et al. 1995). In post-green revolution India, use of profits has either weakened the relationship (Rosenzweig and Binswanger, 1993) or made it disappear entirely (Carter, 1984; Lamb, 2003).

The empirical literature also suggests that rising non-agricultural wages and new technology will affect factor price ratios, supervision requirements, and the presence and extent of market imperfections that might have led to an inverse relationship in the first place (Deolalikar, 1981). More recently, continued subdivision in the context of generational change and the limits on the scope for mechanization by small plot sizes may have contributed to a reversal of the inverse relationship so that, with land market imperfections preventing consolidation, leading to some farms (or more precisely plots) becoming too small for efficient cultivation (Foster and Rosenzweig, 2010).

3. Methodology

Farming households' data from Nigeria allow us to explore determinants of agricultural production and the presence of a farm size-productivity relationship using output as well as measures of profit consistent with types of labor market imperfections at holding and plot level.

3.1 Data

We use data from a 2017/18 Nigerian Baseline Survey (NIBAS) of 3,600 rural households in three agro-ecological zones (Southern Guinea Savanna, Northern Guinea Savanna and Sudan Savanna) and two geo-political zones (North Central and North Western) in Nigeria to provide evidence on the relationship between farm size, and output and profit per unit of cultivated land. The household survey adopted the existing master sampling frame developed by the National Bureau of Statistics (NBS) in a nationwide survey conducted jointly with the World Bank Living Standards Measurement Study (LSMS) team in 2008 for the selection of Enumeration Areas (EAs) for the household listing exercise. A two-stage cluster sample design was used in which rural enumeration areas (EAs) were systematically selected using probability proportional to size (PPS) sampling in the first stage. The sample includes 360 EAs across all six states. Based on household listings, simple random sampling (SRS) of households within EAs was used at the second stage, and approximately 10 households were selected to be surveyed in each EA. It should be noted that we did not exclude households that were non-agricultural. We did not sample with replacement during implementation of the survey.

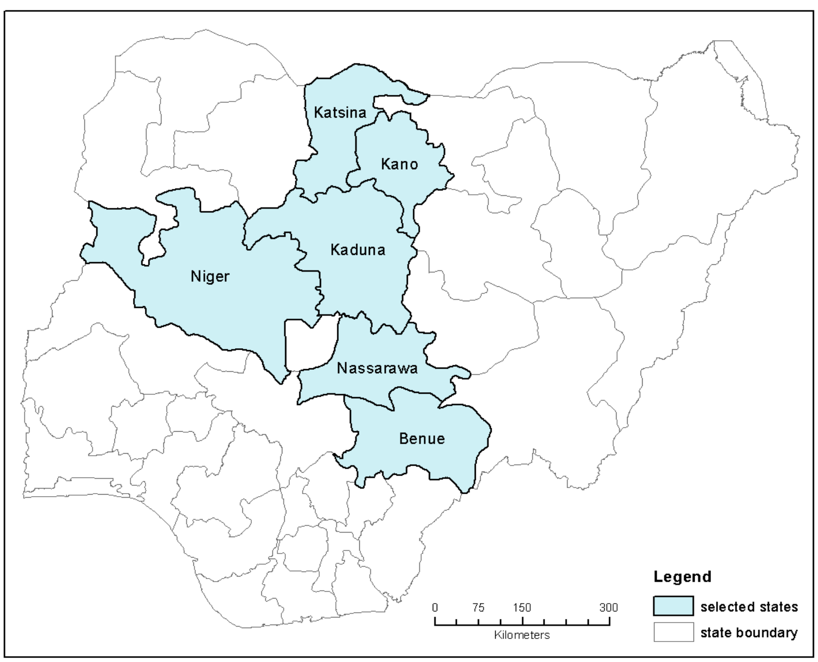

Figure 1. Map of Nigeria showing the six states included in NIBAS

The survey was conducted by the Obafemi Awolowo University in collaboration with the Federal Ministry of Agriculture and Rural Development (FMARD), the National Bureau of Statistics (NBS), and state Agricultural Development Programs (ADPs) with financial support from Bill and Melinda Gates foundation (BMGF). Survey weights (based on the probability of being interviewed and adjusted for the likelihood of remaining in the sample) are used throughout this report to ensure that statistics generated with the sample are unbiased estimates of the population parameters. With survey weights, this data set is representative of the population of rural households. These weights are constructed by multiplying the household weight by the number of a given unit (e.g., hectares) reported by the household. In each household, one person (usually the household head) provided responses for household-level modules. In addition to land characteristics, detailed information was collected on inputs and outputs to compute revenue and profit at plot level and on households' demographics, resource endowments, and participation in land, credit and other markets. Plot-level data on labor and non-labor inputs and output from crop production are for the March-August 2017 agricultural season. To control for unobserved plot-level heterogeneity, we use subjective information on plot characteristics including soil type and topography as well as self-reported land values. For most continuous indicators used in this report, outliers (extreme values) were winsorized at the 1st and/or 99th percentile of the indicator's distribution. All monetary values in this report are reported based on the 2016 value of the naira.

3.2 Econometric approach

Cobb-Douglas and translog production functions at holding- and plot-levels was used to estimate and make inferences on scale of production and technical efficiency across farm size classes and appreciate households' patterns of resource allocation to crop production. The general form of the translog production function with no restrictions on cross elasticities of substitution is (Berndt and Christensen, 1973).

$$Y_{ij} = a_i + \sum_k \beta_k X_{ijk} + \frac{1}{2}\sum_k \sum_l Y_{kl} X_{ijk} X_{ijl} + \delta' Z_{ij} + \epsilon_{ij} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(1)}$$

where Y_{ij} is the total value of crop output (in logarithms) on plot j cultivated by household i; αi is a vector of household fixed effects; X_{ijk} or X_{ijl} are the logarithm of the quantities of variable inputs used (subscripts k and l stand for types of inputs including the number of labor days, quantity of chemical fertilizer, pesticides and manure used); Z_{ij} is a vector of plot characteristics that may affect production, e.g., distance from homestead, years of possession, presence of irrigation or being located in wetland, soil type, topography, and incidence of crop shocks; β, γ, and δ are vectors/matrix of parameters to be estimated; and ϵ_{ii} a random error term. Fixed effects, a_i, at plot or (for household-level regressions) village level include time invariant unobserved factors affecting crop production at the relevant level. Computing the difference between village-level fixed effects and α_i will provide a measure of farmers' ability or technical efficiency (Deininger and Jin, 2008).

Value of crop output and all inputs are normalized by dividing them by their sample means. In the empirical estimation, we also include dummies for zero values of non-labor variable inputs (Battese, 1997). Given symmetry conditions on all cross elasticities (i.e., $\gamma_{kl}= \gamma_{lk}$), the translog function is homogenous if $\Sigma_k\gamma_k$l=0 for all l and it will have constant returns to scale if $\Sigma_k\beta_k$=1. All these restrictions can be tested empirically. Shadow wage rates, i.e., marginal products of different types of family labor, can be calculated by estimating the Cobb-Douglas version of (1) at holding level with family labor disaggregated by gender (Jacoby, 1993).

To analyse the relationship between productivity and farm size at plot or holding level, we estimate an aggregate yield equation following the literature (Assuncao and Braido, 2007, Barrett et al., 2010). The full plot-level specification takes the form:

$$y_{ij} = a_i + \beta A_{ij} + \delta' Z_{ij} + \epsilon_{ij} \ldots\ldots (2)$$

where y_{ij} is the logarithm of the value of crop output per hectare or different profit measures as discussed above on plot j by household i; α_i is a household fixed effect A_{ij} is the logarithm of plot area; Z_{ij} is a vector of plot characteristics that includes subjective land quality measures (soil type, topography, irrigation) and self-reported land values as well as crop dummies and an indicator variable for having experienced plot-specific crop shocks; β and δ are parameters to be estimated and ϵ_{ij} is a random error term. We first estimate a naïve specification that omits Z_{ij} and αi and then control for soil quality and possible market imperfections at village- or household-level. The rationale for doing so is simple: if, as much of the literature seems to suggest, soil quality or market imperfections at household- or village-level are the driving forces for the negative relationship between farm size and productivity, β would be significant in the naïve specification but lose significance once additional elements are introduced and δ as well as αi will be significant. As more intensive use of labor on small holdings or plots was found to not only be a potential reason for the inverse relationship between output and size but also to result in the opposite relationship for profits (Carter, 1984), we run equation (2) not only for yields and profits but also labor demand. We use the log of family days per hectare as a dependent variable at plot- and holding-levels to do so.

4. Results and discussion

4.1 Description at the household and plot level

The descriptive statistics at the household and plot levels are presented in tables 1 and 2, disaggregated by three categories of farm sizes: small (farm size in the first tercile); medium (farm size in the second tercile); and large (farm size in the third tercile).

Table 1: Descriptive Statistics at Household Level

	Total	Small	Medium		Large		Nasarawa	Benue	Kaduna	Niger	Kano	Katsina
Area cultivated & output												
Gross profit per hectare (₦/ha)	1015370.81	1826893.50	443323.24	0.02	770514.63	0.48	989876.36	1117357.84	282312.57	2024277.94	681092.56	1431086.74
Net profit per hectare (₦/ha)	653707.91	1179280.55	192184.44	0.14	586537.22	0.78	925120.61	938124.47	186618.87	1746164.04	422761.78	395682.72
Net shadow profit per hectare (₦/ha)	561821.72	1114917.96	-20461.03	0.10	573624.38	0.90	210993.82	835852.75	156664.03	1686194.52	298264.67	365697.51
Total area planted (ha)	658210.14	1193269.35	192577.13	0.08	591855.40	0.70	927291.21	967832.83	187734.68	1771296.86	422711.55	390671.02
Input use												
Total family labor per hectare	3.85	0.87	2.48	0.00	8.21	0.00	5.58	6.82	2.26	5.00	2.54	3.61
Total communal labor per hectare	91.95	153.34	68.40	0.01	53.63	0.00	112.71	175.82	65.13	88.84	97.10	42.53
Total hired labor per hectare	24.15	61.15	6.09	0.12	4.93	0.08	11.87	12.00	13.62	3.95	66.95	0.90
Share of hired labor	172.03	350.13	92.07	0.00	72.54	0.00	109.32	156.25	115.27	79.43	283.98	161.87
Use of inorganic fertilizer (share)	0.56	0.56	0.57	0.80	0.55	0.03	0.45	0.40	0.60	0.44	0.62	0.68
Inorganic fertilizer rate (kg/ha)	0.82	0.80	0.84	0.33	0.82	0.32	0.64	0.75	0.91	0.68	0.87	0.87
Use of Pesticide	46.73	86.78	39.60	0.05	13.46	0.01	27.08	19.22	18.61	14.30	41.54	128.31
Pesticide rate (kg/ha)	0.69	0.60	0.70	0.00	0.79	0.00	0.91	0.81	0.48	0.89	0.67	0.65
Value of herbicide use	18389.18	50817.00	2696.76	0.05	1410.14	0.02	4921.54	2062.25	1894.79	3290.47	56147.10	7860.38
Herbicide rate (kg/ha)	0.61	0.46	0.64	0.00	0.72	0.00	0.84	0.85	0.82	0.92	0.42	0.21
Value of manure use	11394.58	21136.06	5866.62	0.02	7111.11	0.02	10798.54	12163.61	17532.64	9950.63	14725.87	1571.67
Manure application (kg/ha)	0.46	0.53	0.50	0.19	0.35	0.00	0.10	0.02	0.29	0.17	0.84	0.74
Use of tractor (share)	30.00	66.93	15.58	0.00	7.19	0.00	6.17	0.02	4.04	4.26	82.46	28.38
Area shares												
Share of area planted with grains	-0.01	-0.01	-0.01	0.00	0.00	0.00	0.00	0.00	-0.01	0.00	-0.01	-0.01

Share of area planted with tubers	0.65	0.67	0.68	0.82	0.59	0.00	0.57	0.37	0.87	0.68	0.72	0.57
Share of area planted with trees	0.11	0.07	0.08	0.17	0.17	0.00	0.19	0.51	0.02	0.08	0.01	0.00
Share of area planted with fruit/vegetables	0.00	0.00	0.00	0.32	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Share of area planted with other	0.01	0.00	0.01	0.00	0.01	0.00	0.04	0.00	0.02	0.01	0.00	0.00
Household characteristics												
Age of head	0.24	0.26	0.22	0.61	0.23	0.83	0.20	0.12	0.09	0.24	0.27	0.43
Female head	46.26	45.55	45.87	0.50	47.37	0.01	44.72	48.04	43.49	43.90	46.38	49.37
Head with primary education	0.96	0.95	0.95	0.14	0.98	0.00	0.97	0.91	0.95	0.99	0.97	0.97
Head with secondary education	0.58	0.57	0.57	0.91	0.60	0.38	0.74	0.79	0.67	0.56	0.49	0.44
Number of members<= 15	0.35	0.34	0.35	0.23	0.37	0.12	0.47	0.45	0.45	0.44	0.23	0.26
No of members 15-35	3.67	3.18	3.70	0.00	4.13	0.00	3.40	3.12	3.70	3.97	4.09	3.36
No of members 35-60	2.69	2.25	2.60	0.00	3.23	0.00	3.40	3.40	2.59	2.63	2.55	2.28
No members >=60 _	1.30	1.19	1.28	0.80	1.44	0.00	1.30	1.41	1.18	1.37	1.20	1.42
Household with access to electricity	0.31	0.32	0.30	0.45	0.32	0.52	0.32	0.45	0.24	0.24	0.31	0.33
Household with access to cell phone	0.56	0.59	0.56	0.88	0.52	0.03	0.49	0.32	0.69	0.73	0.52	0.57
Household with access to modern roofing materials	0.78	0.74	0.79	0.01	0.79	0.06	0.75	0.52	0.85	0.94	0.80	0.76
Number of observations (N)	3266.00	1027.00	1026.00	0.00	1213.00	0.00	449.00	461.00	573.00	530.00	511.00	577.00

Source: Own computation from 2017/18 Nigerian baseline survey.

Note: Stars indicated significance levels for t-tests of the equality of means for each of the variables between terciles (* significant at 10%; ** significant at 5%; *** significant at 1%).

We highlight three salient relationships emerging from tables 1 and 2. First, the productivity measures are consistently highest among farms small farms, next highest among medium, and lowest among large farms. Gross profit per hectare and net profit per hectare on small farms are over 15% higher and 40% respectively higher than medium and large farms. Thus table 1 showed that (on the average) the small household farms are superior to the medium and large farm households in term of output. The estimated shadow wages are agrees with households' level of market integration. The profits computed using shadow wages remain negatively related to farm size. However, variations exist across the different states where the survey was conducted. Second, the results further showed that small farms were more labour (communal and hired) intensive than the medium and large farms. At the plot level (table 2), the result showed that while profits computed using shadow wages remain negatively related to farm size, the negative relationship tends to reduce if a measure of profit that values family labor at mean wages is used. Small farmers' superior levels of output can thus be attributed to higher intensity of (hired) labor. This is consistent with the notion that they maximize profits in the presence of market imperfections. Third, input (herbicide and manure) costs per hectare are lowest among the large farms and highest among small farms.

This may also suggests that marginal products of labor differ significantly across farm size groups. Assumptions regarding the nature of labor market imperfections and the resulting valuation of family labor will thus affect the nature of the relationship between farm size and output. Kernel-weighted nonparametric regressions for the logarithms of crop output value against holding or plot size in figure 2 and labor use in figure 3 illustrate this descriptively.

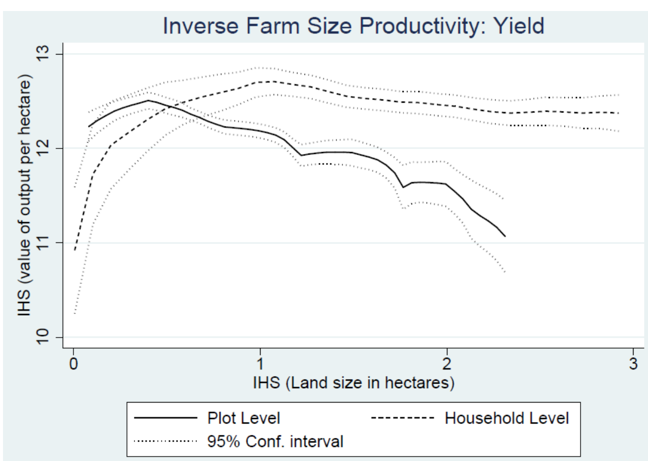

Figure 2

Table 2: Descriptive Statistics at Plot Level

	Total	Small	Medium		Large	
Area cultivated & output						
Profit per hectare (₦/ha)	962911.41	1295668.94	779907.96	0.93	627726.52	0.71
Net profit with family labor per hectare (₦/ha)	631704.19	825447.99	552276.34	0.76	401016.83	0.83
Net shadow profit with family labor per hectare (₦/ha)	511239.29	629905.85	451229.37	0.71	386369.57	0.99
Area of plot (ha)	635662.01	831563.26	553764.52	0.83	405391.52	0.74
Input use						
Labor days (total) per hectare	1.09	0.34	0.93	0.00	2.74	0.00
Use inorganic fertilizer	336.69	610.44	152.76	0.00	103.39	0.00
Quantity of inorganic fertilizer per hectare (kg/ha)	0.63	0.61	0.65	0.00	0.63	0.27
Use pesticide	44.25	82.83	17.34	0.00	12.84	0.01
Value of pesticide used per hectare	0.53	0.51	0.52	0.00	0.61	0.00
Value of herbicide used per hectare	7650.64	15588.01	2245.49	0.00	992.86	0.00
Use herbicide	0.49	0.42	0.50	0.00	0.62	0.00
Value of manure used per hectare	11866.88	18927.70	8219.31	0.01	4207.79	0.00
Use manure	0.34	0.39	0.34	0.00	0.27	0.00
Use tractor	26.08	50.33	9.89	0.00	5.25	0.00
Area shares						
Share of area planted with grains	0.15	0.13	0.14	0.02	0.18	0.00
Share of area planted with tubers	0.62	0.62	0.64	0.02	0.61	0.00
Share of area planted with trees	0.12	0.11	0.10	0.00	0.17	0.00
Share of area planted with fruit/vegetables	0.00	0.00	0.00	0.47	0.00	0.75
Share of area planted with other	0.01	0.01	0.01	0.00	0.01	0.00
Plot characteristics						
Plot is intercropped	0.25	0.27	0.25	0.60	0.22	0.00
Flat land	0.07	0.06	0.07	0.00	0.10	0.00
Gently slopped land	0.87	0.88	0.87	0.94	0.87	0.80
Plot is irrigated	0.12	0.10	0.14	0.10	0.13	0.48
Sand soil	0.07	0.06	0.07	0.08	0.08	0.42
Loam soil	0.40	0.44	0.40	0.00	0.34	0.00
Clay soil	0.56	0.52	0.58	0.00	0.61	0.00
Other soil	0.07	0.06	0.07	0.93	0.09	0.00
Plot is fertile	0.66	0.66	0.66	0.24	0.64	0.01
Number of observations (N)	12,161	4,852	4,156	0	3,153	0

Source: Own computation from 2017/18 Nigerian baseline survey.
Note: Input use is reported only for those who applied positive amounts. Stars indicated significance levels for t-tests of the equality of means for each of the variables between terciles (* significant at 10%; ** significant at 5%; *** significant at 1%).

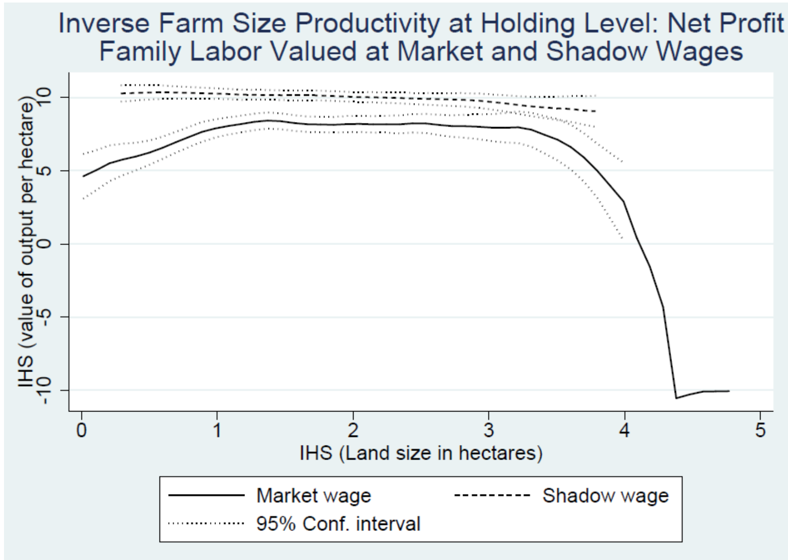

Figure 3

4.2 Econometric estimates

The top panel of table 3 reports parameter estimates from the Cobb-Douglas and translog specifications at household (columns 1-3) and plot (columns 4 - 6) level, respectively. We note that none of conventional factors are significant. Irrigation is estimated to increase output by 22% points, while herbicide also reduced output by some 15 points. Plot level regressions also point towards a positive impact of application of pesticide and irrigation system; one litter of pesticide and irrigation water to could help to increase output by about 89% and 22% points respectively. Estimates of technical efficiency from a stochastic frontier production function, plotted against holding size in figure 3 together with a kernel-weighted local polynomial regression fitted through them, has demonstrated a significant support for a systematic relationship between efficiency and size. Plotting this variable and the regression fitted through it against cultivated area in figure 4 points in the same direction.

Table 3: Parameter Estimates and Output Elasticities for Alternative Specifications of the Production Function

	Holding level			**Plot level**		
	Translog	**Cobb-Douglas**		**Translog**	**Cobb-Douglas**	
	0.173	-0.220***	-0.338***	-0.897	0.721***	0.28**
	(0.404)	(0.053)	(0.074)	(0.583)	(0.124)	(0.115)
Log labor days	-0.511	0.429***	0.251***	-1.075***	0.245***	
	(0.483)	(0.036)	(0.037)	(0.144)	(0.051)	
Log male family labor days			--0.150***			-0.506***
			(-3.20)			(0.182)

Log female family labor days			-0.006			0.483***
			(0.020			(0.115)
Log hired labor days			0.251***			0.745***
			(0.073)			(0.177)
Log chemical fertilizer use in kg	0.423***	0.151***	0.164***	0.589***	0.118***	0.141***
	(5.22)	(5.66)	(4.70)	(-0.65)	(4.01)	(0.039)
Log pesticide use in US$	0.057	0.075***	0.041***	-0.169	0.005	-0.025
	(0.69)	(5.82)	(2.89)	(-6.91)	(0.77)	(0.016)
Log manure use in kg	0.501***	0.100***	0.056	1.300***	0.548***	-0.046
	(2.67)	(3.18)	(1.24)	(13.03)	(17.87)	(0.041)
Log herbicide	-0.155*	0.177***	0.206***	-0.221**	0.153***	0.125***
	(0.090)	(0.036)	(0.03)	(0.101)	(0.041)	(0.035)
Fertilizer use	-0.353***	-0.146**	-0.204***	0.071	0.195	0.139
	(0.100)	(0.072)	(0.078)	(0.245)	(0.176)	(0.163)
Pesticide use	-0.001	-0.022	-0.042	0.890***	0.647***	0.692***
	(0.064)	(0.061)	(0.060)	(0.291)	(0.270)	(0.252)
Manure use	0.229	-0.027	-0.050	0.011	-0.126	-0.152
	(0.333)	(0.086)	(0.086)	(0.248)	(0.137)	(0.135)
Log land X Log labor	0.023			0.443***		
	(0.057)			(0.083)		
Log land X Log fertilizer	-0.043			-0.060		
	(0.028)			(0.048)		
Log land X Log pesticide	-0.009			-0.010		
	(0.010)			(0.021)		
Log land X Log manure	-0.070***			-0.134***		
	(0.025)			(0.045)		
Log land X Log herbicide	-0.019**			-0.008**		
	(0.010)			(0.022)		
Log labor X Log fertilizer	-0.007			-0.063**		
	(.0025)			(0.028)		
Log labor X Log pesticide	-0.002			-0.0019		
	(0.006)			(0.013)		
Log labor X Log manure	-0.064***			-0.011		
	(0.018)			(0.020)		
Log labor X Log herbicide	-0.018***			-0.001		
	(0.007)			(0.009)		
Log fertilizer X Log pesticide	-0.002			-0.005		
	(0.004)			(0.005)		
Log fertilizer X Log manure	0.018			-0.001		
	(0.011)			(0.012)		
Log fertilizer X Log herbicide	-0.000			0.019***		
	(0.004)			(0.007)		
Log pesticide X Log manure	-0.000			-0.008**		
	(0.002)			(0.004)		
Irrigated land	0.221**	0.221*	0.318***	0.221**	0.221*	0.318**
	(0.112)	(0.113)	(0.118)	(0.112)	(0.113)	(0.118)
Share of area cultivated with tubers	-0.417	-0.427	-0.510	-0.417	0.427	-0.510
	(0.407)	(0.441)	(0.458)	(0.407)	(0.441)	(0.458)
Share of area with tree crops	0.268	0.239	0.283	0.283	0.268	0.239
	(0.381)	(0.336)	(0.399)	(0.381)	(0.336)	(0.399)
Constant	9.083***	10.198***	12.344***	13.725***	10.386***	12.038***
	(1.483)	(0.384)	(0.344)	(0.694)	(0.602)	(0.489)
Number of observations	3,077	3,077	3,077	11,510	11,510	11,510
Output elasticities						
Land	-0.275	-0.203	-0.338	0.815	0.721	0.283
	(0.052)	(0.053)	(0.074)	(0.111)	(0.124)	(0.115)

Labor	0.365	0.429	0.125	0.362	0.245	0.948
	(0.034)	(0.036)	(0.047)	(0.046)	(0.051)	(0.151)
Fertilizer	0.203	0.151	0.164	0.197	0.118	0.141
	(0.0320	(0.027)	(0.029)	(0.074)	(0.038)	(0.039)
Pesticides	0.007	0.016	0.018	-0.055	-0.016	-0.025
	(0.008)	(0.006)	(0.006)	(0.038)	(0.017)	(0.016)
Manure	-0.128	-0.018	-0.004	-0.0169	-0.096	-0.046)
	(0.59	(0.024)	(0.024)	(0.112)	(0.042)	(0.041)
Herbicide	0.085	0.177	0.206	0.074	0.153	0.125
	(0.026)	(0.036)	(0.039)	(0.027)	(0.040)	(0.035)

Note: All holding-level regressions include village fixed effects while plot-level regressions are estimated using household fixed effects. Most of the Allen cross elasticities are not statistically different from zero. Absolute value of t-statistics in parenthesis: *** significant at 1%; ** significant at 5%; * significant at 1%.

4.3 Evidence on the farm size-productivity relationship

Regression results from tables 4-6 attempts to examine the relationship between farm size and productivity with respect to yields (table 4), labor use (table 5), and shadow profits (table 6) both at holding and plot levels. In all cases, we start with a naïve specification that includes only cropped area (columns 1 and 4 at holding and plot-level, respectively) and successively add variables to control for soil quality (type, topography, presence of irrigation, among others). Findings from regression analysis as presented in table 4 indicated a strong negative relationship between the value of output per hectare and own cultivated area with a doubling in cultivated area associated with a 35% or 98% decrease in the value of crop output per unit of cultivated land at the holding- or plot-level, respectively. Other attributes such as irrigation, soil type, and topography, all have the expected signs, are highly statistically significant and their inclusion improves the explanatory power of the regression (columns 3 and 5). Still, the magnitude of the estimated farm size productivity relationship is hardly affected. This suggests that, despite descriptive variation in plot attributes with size as suggested by table 2, land quality and village level market imperfections are not at the root of the regularity. Including observed household characteristics such as head's age and education or female headship provides interesting insights. For instance, the age of household head may account for the difference in household's participation in factor market regardless of the gender on the household.

Table 4: Farm Size Productivity Relationship: Yield Approach

	Holding Level			**Plot level**			
Cropped area(ha)	-0.349***	0.454***	-0.558***	-0.982***	-0.552***	-0.462***	-0.423***
	(0.036)	(0.057)	(0.052)	(0.196)	(0.172)	(0.135)	(0.129)
Irrigated land		0.863***	0.696***		0.020	0.531***	0.573***
		(0.135)	(0.134)		(0.237)	(0.121)	(0.111)

Flat land		-0.061	-0.076		-0.216	-0.337*	-0.363**
		(0.200)	(0.188)		(0.315)	(0.193)	(0.154)
Gently slopped land		-0.139	-0.157		0.028	-0.178	-0.213*
		(0.186)	(0.177)		(0.280)	(0.163)	(0.126)
Sand soil		0.187	0.169		1.026***	0.549***	0.520***
		(0.251)	(0.234)		(0.317)	(0.166)	(0.163)
Loam soil		0.151	0.172		1.106***	0.425***	0.399***
		(0.243)	(0.299)		(0.351)	(0.157)	(0.169)
Clay soil		0.274	0.235		1.436***	0.735***	0.777***
		(0.228)	(0.216)		(0.429)	(0.219)	(0.193)
Fertile		-0.052	-0.056		0.434	-0.113	-0.101
		(0.074)	(0.067)		(0.0288)	(0.116)	(0.100)
Tree crop			0.413			-0.787	-0.759**
			(0384)			(0.572)	(0.373)
Age of head			-0.004*			-0.009*	-0.011**
			(0.002)			(0.005)	(0.004)
Female head			-0.010			-0.111	-0.031
			(0.274)			(0.259)	(0.258)
Primary education			-0.041			0.057	-0.084
			(0.083)			(0.137)	(0.118)
Secondary education			0.100			-0.120	-0.096
			(0.072)			(0.157)	(0.144)
No of members<=15			0.023**			0.028	0.040**
			(0.010)			(0.019)	(0.017)
No of members 15- 35			0.053***			0.050**	0.059**
			(0.017)			(0.025)	(0.023)
No of members 35- 60			0.085***			0.019	0.009
			(0.032)			(0.044)	(0.045)
No of members >=60			-0.023			0.022	0.091
			(0.0730			(0.096)	(0.091)
Constant	13.335***	13.279***	13.117***	13.212***	11.323***	11.625***	12.986***
	(0.066)	(0.251)	(0.420)	(0.176)	(0.376)		(0.441)
No of observations	3,101	3,101	3,101	11,589	11,589	11,589	11,589
R-squared	0.057	0.378	0.417	0.049	0.586	0.187	0.114

Note: Regressions are for owned plots only (see separate appendix for results with all plots).Absolute value of t-statistics in parenthesis: *** significant at 1%; ** significant at 5%; * significant at 1%.

The result from equivalent regression is presented in table 5. The results from labor demand suggesting that use of labor per area declines steeply, with an estimated elasticity of about -0.39 in a household's cultivated area (columns 1-3) and -0.73 in plot size (columns 4-7). Use of labor is also estimated to increase with land quality as proxied by the availability of irrigation facility, quality of soil and topography of the land. The high significance of coefficients on household composition (members 35-60; 15-35 and less than 15 years old) suggest active and available labor markets.

Table 5: Farm Size and Intensity of Labor Use

	Holding Level			**Plot Level**			
Cropped area(ha)	-0.396***	-0.613***	-0.682***	-0.732***	-0.919***	-0.951***	-0.915***
	(0.022)	(0.035)	(0.031)	(0.073)	(0.055)	(0.064)	(0.059)
Irrigated land		0.572***	0.610***		1.008***	0.743***	0.575***
		(0.127)	(0.121)		(0.261)	(0.142)	(0.110)
Flat land		-0.169	-0.220		0.290*	-0.103	-0.176
		(0.146)	(0.141)		(0.176)	(0.116)	(0.111)
Gently slopped land		-0.103	-0.158		0.321*	-0.003	-0.085
		(0.144)	(0.141)		(0.176)	(0.116)	(0.111)

Sand soil		0.010	0.019		0.513***	0.322***	0.272***
		(0.142)	(0.140)		(0.132)	(0.085)	(0.078)
Loam soil		0.125	0.144		0.475***	0.339***	0.255***
		(0.159)	(0.158)		0.128)	(0.098)	(0.095)
Clay soil		0.123	0.117		0.650***	0.308***	0.208*
		(0.168)	(0.172)		(0.198)	(0.114)	(0.110)
Tuber			-0.160			-0.291	-0.384*
			(0.191)			(0.264)	(0.207)
Tree crop			0.510*			1.151***	1.119***
			(0.293)			(0.295)	(0.490)
Age of head			0.000			0.002	0.003
			(0.002)			(0.003)	(0.003)
Female head			-0.063			0.015	-0.034
			(0.155)			(0.199)	(0.198)
Primary education			0.013			-0.131	-0.147
			(0.071)			(0.116)	(0.093)
Secondary education			-0.008			0.118	0.111
			(0.057)			(0.090)	(0.089)
No of members<=15			0.018**			0.005	0.015*
			(0.007)			(0.010)	(0.009)
No of members 15- 35			0.047***			-0.004	0.001
			(0.010)			(0.013)	(0.012)
No of members 35- 60			0.070***			-0.066**	0.072***
			(0.021)			(0.026)	(0.026)
No of members >=60			0.004			0.046	0.049
			(0.048)			(0.049)	(0.046)
Constant	6.259***	6.518***	6.229***	5.735***	4.972***	5.583***	5.876***
	(0.044)	(0.158)	(0.266)	(0.082)	(0.218)		(0.310)
No of observations	3,101	3,101	3,101	11,589	11,589	11,589	11,589
R-squared	0.133	0.402	0.442	0.099	0.750	0.277	0.217

Note: Regressions are for owned plots only. Absolute value of t-statistics in parenthesis: *** significant at 1%; ** significant at 5%; * significant at 1%.

Table 6 reports estimates of the relationship between farm size and per hectare shadow profit net of purchased inputs and male and female family labor valued at their estimated marginal products. These estimates indicate that smaller farms are significantly more profitable; the magnitude of the (negative) per hectare profit elasticity of land size is broadly equal to that obtained for per hectare value of crop output. An inverse relationship between shadow profit and farm size emerges robustly at holding and plot level. This is affected by inclusion of plot characteristics, soil quality and household specific fixed effects such age and gender of the household's head. In summary, these findings imply that, although yield and shadow profits decrease significantly with farm or plot size there may need to resort to unobserved differences in land quality or measurement error to explain these.

Table 6: Farm Size Productivity Relationship: Net Profit Approach Using Shadow Wages

	Holding Level			Plot Level			
Cropped area(ha)	-0.0317	-0.012	-0.224	-2.687***	-1.016*	-0.428	-0.086
	(0.397)	(0.433)	(0.437)	(0.743)	(0.570)	(0.398)	(0.433)
Irrigated land		0.265	-0.007		-3.810**	0.214	0.16
		(1.199)	(1.257)		(1.627)	(0.663)	(0.798)
Flat land		2.314*	2.771**		-1.045	-0.653	-1.278*

		(1.382)	(1.390)		(1.368)	(0.754)	(0.720)
Gently slopped land		1.446	1.779		-0.345	-0.590	-1.293*
		(1.219)	(1.259)		(1.288)	(0.683)	(0.660)
Fertile land		-2.108***	-2.052***		0.282	-0.713	-0.541
		(0.670)	(0.678)		(0.801)	(0.476)	(0.485)
Sand soil		-1.049	-1.213		-0.014	-1.507***	-0.689
		(1.765)	(1.759)		(1.139)	(0.615)	(0.685)
Loam soil		-1.049	-1.037		1.336	-1.791	-1.131*
		(0.7650	(1.759)		(1.120)	(0.617)	(0.644)
Clay soil		-0.440	-0.709		-0.357	-1.105	-0.625
		(2.257)	(2.276)		(1.419)	(0.783)	(0.757)
Tubers			-0.487			-1.752	-3.754**
			(2.217)			(1.622)	(1.704)
Tree crop			5.884**			5.496	3.362
			(2.309)			(3.579)	(7.343)
Age of head			-0.064**			-0.055***	-0.036
			(0.026)			(0.019)	(0.022)
Female head			-2.012			-2.703*	-3.255***
			(1.706)			(1.392)	(1.208)
Primary education			-0.415			-0.262	-0.563
			(0.608)			(0.475)	(0.397)
Secondary education			0.446			-0.084	0.065
			(0.686)			(0.491)	(0.519)
No of members<=15			0.007			-0.046	-0.005
			(0.095)			(0.075)	(0.079)
No of members 15- 35			0.171			0.232**	0.289***
			(0.116)			(0.093)	(0.089)
No of members 35- 60			0.948***			0.495**	0.369*
			(0.339)			(0.233)	(0.211)
Constant	8.122***	8.561***	13.078***	8.472***	6.912***	17.306***	24.482***
	(0.707)	(1.681)	(2.699)	(0.712)	(1.445)		(1.711)
No of observations	3,101	3,101	3,101	11,589	11,589	11,589	11,589
R-squared	0.001	0.279	0.290	0.021	0.619	0.231	0.109

Note: Regressions are for owned plots only. Profit elasticity of land is calculated at mean values. Absolute value of t-statistics in parenthesis: *** significant at 1%; ** significant at 5%; * significant at 1%.

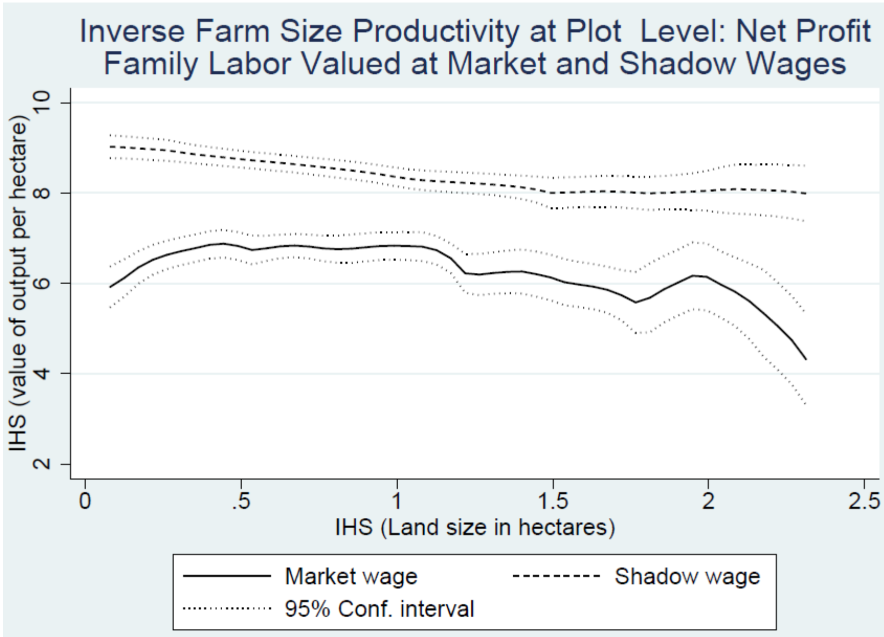

Figure 4

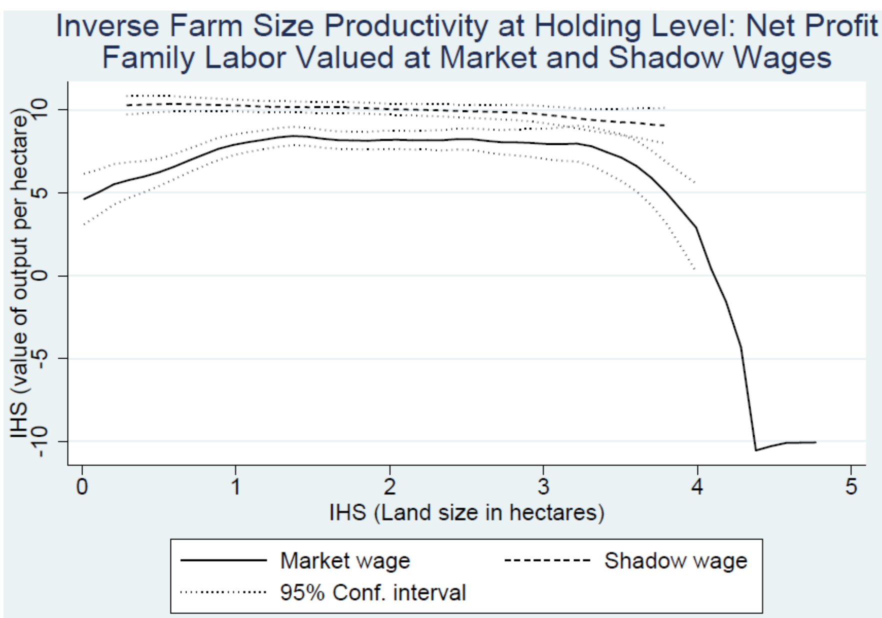

Figure 5

Conclusion and policy implication

The paper analysed the relationship between farm size and productivity, applying data from a cross section household baseline survey of Nigeria, and tested the inverse relationship between farm size and productivity. Output per hectare was used, and evidence found consistent and stable in both. The results of extended regression equations included the soil quality, topography, irrigation facilities and other socio-economic variables of the households. The results are significant and consistent with the models of output per hectare, reflecting that small farms use more input and labour unit per hectare than do large farms. The coefficients of family size both in output and in labour hours per hectare reveal the importance of labor and other inputs on farm productivity in most part of rural areas. We show that a mild U-shape relationship between yield and cropping area is restored from an inverse U-shape curve when the farm fixed effects are properly accounted for. In addition to differences in some farming practices, farm input choice between labor and capital may have played a more important role in contributing to the changed farm size–productivity relationship. We find a robust negative relationship between farm size and per hectare gross output and shadow profit that tend to reduce if plot characteristics or household attributes are controlled for. More intensive labor use by smaller farms is a key underlying reason. The fact that results at plot level are essentially identical and did not allow us to reject the notion of a relationship between plot size and net profits at market prices even for the smallest size group, reinforces this conclusion. In terms of policy, it suggests that, given the importance of factor market imperfections emerging from our analysis, in-depth analysis of key factor markets and their interactions will be desirable.

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