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SPILLOVER EFFECTS OF MEDIUM-SCALE FARMS ON SMALLHOLDER BEHAVIOUR AND WELFARE: EVIDENCE FROM NIGERIA

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ACRONYMS

APRA	Agricultural Policy Research in Africa
CFA	Control Function Approach
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station
IV	Instrumental Variable
LGA	Local Government Area
LSF	large-scale farm
MSF	medium-scale farm
SME	small and medium-sized enterprise
SSF	small-scale farm

1 INTRODUCTION

A rapid change in farm size distributions is taking place across sub-Saharan Africa. Many countries are experiencing an increasing share of farmland under medium-scale farms (MSFs) between 5ha and 100ha (Jayne *et al*. 2016). The share of land owned by these emerging MSFs range from about 20 per cent in Kenya, to 32 per cent in Ghana, 37 per cent in Tanzania, and as high as 53 per cent in Zambia (Jayne *et al*. 2019). These MSFs co-exist with small-scale farmers (SSFs) operating on less than 5ha, who still constitute the majority of households in rural areas of Africa. While there is a growing amount of literature documenting the drivers of the rise of MSFs (Anseeuw *et al*. 2016; Jayne *et al*. 2016) and their characteristics (Jayne *et al*. 2019; Muyanga *et al*. 2019; Muyanga and Jayne 2019), empirical evidence on how this rise in MSFs impacts neighbouring SSFs is thin.

Compared to large-scale farms (LSFs) operating between 5ha and 100ha, MSFs tend to be more socio-culturally similar to SSFs in the communities where they are located (Chamberlin and Jayne 2020; Wineman *et al*. 2020; Houssou, Chapoto and Asante-Addo 2016). Due to their smaller size, they are also more likely than LSFs to be interested in coordinating input purchase or output sales with SSFs. Despite increasing recognition of these potentially stronger spillover effects of MSFs, the majority of the existing empirical literature has focused on spillover effects of LSFs (Ali, Deininger and Harris 2019; Burke, Jayne and Sitko 2019; Glover and Jones 2019; Xia and Deininger 2019; Lay, Nolte and Sipangule 2018; Herrmann 2017). A few studies such as Wineman *et al*. (2020) and Burke, Jayne and Sitko (2019) examine the spillover effects of MSFs between 5ha and 50ha. In these studies (as in most of the literature on large farms), identification of spillover effects relies on changes in SSF behaviour due to their proximity to larger farms, conditional on variables likely to be correlated with the location decisions of medium and large farms and farmer behaviour. While they are able to speculate on reasons for identified relationships between SSF behaviour and the presence of MSFs, they are unable to identify the actual mechanisms that generate these spillover effects. They are also unable to determine if certain potential mechanisms (e.g. improved access to input or output markets versus sales coordination or knowledge transfers) are more important for particular SSF outcomes such as input use or productivity. Finally, we are aware of no studies that have explored the effects of the rise in MSFs on the incomes, productivity and degree of farm commercialisation of neighbouring SSFs.

Thus, this paper addresses these three observed gaps in the literature. We develop a theoretical model to explain some mechanisms through which spillovers on SSFs can be generated from the existence of larger farms around them. We empirically test this with data from Nigeria; Africa's largest economy and most populous nation. Secondly, we focus exclusively on MSFs (operating 5ha to 50ha) as enterprises that are likely to be more accessible to SSFs than LSFs.[1] Thirdly, we explore the spillover effects of MSFs on a broader set of SSF outcomes including input use, productivity, commercialisation and welfare captured via several measures of household income and poverty status. In short, this paper provides a more comprehensive view of spillover effects.

Using comparative statics, our theoretic model yields some important empirical predictions – the effect of proximity to an MSF is mediated through knowledge spillovers, which we refer to as 'learning effects' and the ability of the MSF to reduce the input-related costs of the SSF, which we define as a 'cost effect.' We characterise the learning effect as the result of receiving productivity-enhancing training from an MSF while the cost-reducing effect emerges from reduced transaction costs from purchasing input from a neighbouring MSF. We also explore the welfare effect of a third channel of selling output to the MSF since this may generate a combined learning and cost effect. This would occur if for example, MSF provide training, input access and/or other forms of guidance to SSFs to meet the requirements of their buyers in addition to reducing SSFs' cost of finding a market.

Interactions between SSFs and MSFs are hardly random. More progressive SSFs may self-select into beneficial relationships with MSFs, which potentially confounds identification and could lead to biased estimates of the spillover effects. To address this, we use a two-step Control Function Approach (CFA) as proposed by Wooldridge (2015). The key explanatory variables of interest: learning, cost and sales coordination effects are instrumented with the number of MSFs in the Local Government Area (LGA) of the SSF, conditional on LGA-level socio-economic and agro-ecological factors (likely to attract MSFs) as well as farmer and plot level characteristics. We argue the appropriateness of excluding the instrument in a falsification-like test and examine the robustness of our findings to alternative considerations.

Consistent with theoretical predictions, we find evidence of knowledge and cost spillover effects of MSFs on SSF behaviour and welfare. Receiving training and purchasing inputs from a MSF increases SSF productivity (yields) and welfare via increased incomes and lower poverty incidence and severity of poverty. While receiving training increases the likelihood and intensity of improved seed use, it has no effect on the use of fertiliser or crop protectants. Surprisingly, purchasing inputs from a MSF has no positive impact on any modern input use. This implies that the increased productivity observed from farmers who purchased inputs from MSFs is likely driven by improved access to higher-quality inputs; a big challenge in sub-Saharan Africa (Poku, Birner and Gupta 2018) or the provision of training or other complementary services alongside the sale of inputs. While other studies have found a positive effect of proximity to large farms on yields and/or input use or welfare (Glover and Jones 2019; Deininger and Xia 2018; Lay, Nolte and Sipangule 2018), none that the authors are aware of have been able to identify how that improvement came about. This study finds that for Nigeria, knowledge spillovers from actual training is driving limited expansion of modern input use and significantly enhancing farmer productivity and income. Direct access to inputs through MSF increases productivity but this is not through increased likelihood (or quantity) of modern input use.

Compared to all interactions, improved access to output markets via sales to MSFs has the strongest welfare effects for SSFs. The opportunity to sell through MSFs enables SSFs to receive a higher price; thereby boosting their crop and total income. This reduces their probability of being in poverty as well as the extent and severity of poverty they experience. Higher yields associated with sales coordination could occur through investments made in agricultural production to take advantage of improved access to a more guaranteed market and/or training offered to support the coordination activities of MSFs.[2] This is consistent with Liverpool-Tasie *et al.* (2020), who find that market outlets (e.g. agro-processors and wholesale traders) in the midstream of food value chains in developing countries are increasingly offering SSFs complementary services such as as training and other inputs to ensure that they can get the quantity and quality of products to meet their needs. On exploring this further, we find strong evidence that SSF productivity and welfare are significantly enhanced by more intense interaction with MSFs.

These findings have important implications for policy-makers across Africa as they strive to improve SSF welfare while creating an environment for expanded food production to meet the demands of rapidly growing populations and changing dietary patterns. This paper finds evidence in support of policies to encourage the beneficial co-existence of medium and small-scale farms. It documents the important role that MSFs are playing in improving SSF productivity and welfare via improved management practices and the opportunity to sell their output at more competitive prices. Finally, this study demonstrates that multiple interactions such as market access alongside training are necessary for positive productivity and welfare effects, which should be encouraged.

The remainder of the paper is organised as follows: Section 2 provides a review of the literature on interactions between small, medium and large-scale farms while Section 3 presents our theoretical model. Section 4 describes the data used while Section 5 presents the empirical strategy. Sections 6 presents the main study results while Section 7 presents our robustness checks. Section 8 concludes.

2 BACKGROUND: MECHANISMS OF INTERACTION BETWEEN SMALL AND MEDIUM AND/OR LARGE FARMS

The potential spillovers from larger farms to small farms could be positive or negative. MSFs and LSFs can enhance SSFs' access to improved inputs and new technologies by bringing these resources to the areas in which they operate and making them more readily available to neighbouring small farms (Jayne *et al*. 2014; Amanor 2011). If a high concentration of MSFs attracts private investment in farm input supply and service provision, we may expect small-scale farmers in such areas to face lower transaction costs of acquiring inputs. Moreover, SSFs may purchase inputs or services directly from MSFs, also contributing to lower costs.[3]

MSFs and LSFs are often hailed as potential mechanisms for knowledge diffusion in rural areas. They can promote technology adoption via demonstration effect or their ability to experiment and discover new crops suited to a particular agroecology (Ali, Deininger and Harris 2019; Deininger and Xia 2018; Deininger and Xia 2016). Larger farms tend to demand specific (often high) input quality standards (Prowse 2012). With the challenges associated with input quality in many African countries (Bold *et al*. 2017), larger farms also have more of an incentive (compared to small farms) to verify the quality of these inputs; given their importance in crop productivity and because they purchase inputs in large quantities. Thus, if SSFs are able to procure inputs from or with these MSFs, they can potentially avoid low quality inputs (Ali *et al*. 2016), yielding higher productivity. This productivity-enhancing spillover may be complemented by knowledge spillovers that occur if larger farms hire and train labour from the local community or offer direct training services to SSFs, resulting in positive learning effects. Separate from learning, the opportunity for wage employment for SSFs is a potentially important source of income and improved livelihood for land-constrained households (Wineman *et al*. 2020; Van den Broeck, Swinnen and Maertens 2017; Neven *et al*. 2009)

Conversely, MSFs (similar to LSFs) may induce negative spillovers on SSFs. These include higher food prices in areas with commercial farms (Schoneveld, German and Nutakor 2011) as labour shifts from food production on small farms to large single-crop farms (Pryor and Chipeta 1990). They might also crowd out SSF access to modern inputs where supply in particular geographic locations is limited. In the absence of cooperative interaction with SSFs, the presence of MSFs in an area could divert limited government and/or private extension services to the larger farms. In addition, lands suitable for community/small-scale farming could be diverted towards medium and large-scale and commercial farming – displacing SSFs and/or putting upward pressure on both land rental and sales price (Jayne *et al*. 2012; Lundahl 2015).

These potentially conflicting effects of MSFs on neighbouring small farms is borne out in the existing literature (largely on large farms) and has led to a general lack of consensus in the literature on the precise effects of larger farms. For example, while Deininger and Xia (2016) find positive short-term effects of proximity to a large farm on smallholder adoption of new practices and job creation in Mozambique, they do not find that LSFs improved the access of small farms to input and output markets. This contrasts with Ali, Deininger and Harris (2016) and Deininger and Xia (2018) that both find some positive effects of input use and risk-coping among small farms but not employment creation in Ethiopia. In Zambia, while Lay, Nolte and Sipangule (2018) find evidence of some positive spillovers on the ability of SSFs to expand their acreage, they also find reduced input (fertiliser) use associated with areas with high incidence of large farms. In addition, Deininger and Xia (2016) found that proximity to larger farms decreased the perceived well-being among local people due to disruptions in rural socio-economic structures (Deininger and Xia 2016; Smalley 2013). This negative externality may be reinforced by the acquisition of large areas of lands by real estate firms as they speculate on the land prices in the vicinity of new MSFs (Smalley 2013); making it harder for poor landless people to obtain lands.

This paper contributes to this ongoing debate with a novel analysis from a largely unexplored (for this topic) but important country in Africa; Nigeria. We develop a theoretic framework to test some of these spillover effects (particularly knowledge and cost spillover effects) and then empirically test for evidence of these in our data from Nigeria. We consider the effects of MSFs on the input use decisions, subsequent yield, sales and ultimate welfare of SSFs around them.

3 THEORETICAL FRAMEWORK

We provide a simple framework for understanding how proximity to a MSF may yield spillover effects on neighbouring SSFs. Consider a small-scale farming household in the spatial neighbourhood of a MSF that maximises utility $U(c,l,\alpha)$ where c,l and α refer to consumption, leisure, and a vector of household level covariates respectively. The household maximises utility subject to its budget constraint given by

$$c = p * f(x(\omega), L, n, z) - C(\omega(v+t), L, h) - wn^h + wn^o + I \equiv M$$

where consumption, c, is bounded by income, M, and v and t refer to transport and other transactions costs respectively. Here, p is output price, $f(\cdot)$ is a twice differentiable concave production function of non-labour inputs $x(\omega)$, proximity to a MSF, L and labour, n which equals the sum of hired labour n^h and family labour n^f. Let $C(\cdot)$ be cost function associated with production of all non-labour inputs. As standard, we maintain that the utility function is a concave and twice continuously differentiable function of c, l, and α. We will return to the meaning of ω subsequently. Quasi-fixed factors such as agroecological conditions of the farming area that affect farm output are represented by z. In addition to farm output income, the household has exogenous income I, earns a competitive wage, w from selling labour off-farm, n^0 and hires labour, n^h for the same wage w. For simplicity, we chose to make labour cost additive. The household's time endowment is defined as T. Then it follows that the household utility maximisation problem can be summarised as:

$$Max_{c,l}\, U(c, l, a) \text{ subject to } c = f(x(\omega), L, n, z) - C(\omega(v+t), l, h) - wn^h + wn^o + I \equiv M \quad (1)$$

Where output price is normalised to 1

$$T = l + n^f + n^o \text{ and } n = n^f + n^h \quad (2)$$

Here, proximity to the MSF affects the utility of the household through its effect on SSF's full income $Y(\cdot)$ i.e. profits plus other exogenous non-farm income.
Where

$$Y(\cdot) = p * f(x(\omega), L, n, z) - C(\omega(v+t), L, h) - wn^h + wn^o + I$$

Let the optimal utility from this problem be given by the indirect utility function

$$U^* = v(M^*, w, a) \quad (3)$$

Clearly, U^* is a function of optimal income (and thus farm profits) which in turn depends on proximity to the MSF, L. Thus, to obtain the effect of proximity to the MSF on SSF utility, we evaluate its effect on the household's profit function and hence income. To simplify this analysis, we consider a case where the SSF has to exert some effort, ω, to access inputs. The effort, ω includes transport costs v and other transaction costs t. Total input related costs (beyond market price) can be represented as $\delta = v + t$. Then input use, $x(\cdot)$, is an increasing function of efforts, ω, but is also decreasing in input-related costs δ. The input-use function $x(\cdot)$ together with quasi-fixed factors, z, enter the farmer's production function, $f(\cdot)$ to determine the farmer's output. Also, we assume that proximity to the MSF, L, affects the small farm's input use through knowledge spillovers, i.e. the learning effect. For now, we assume proximity to the MSF as given. We shall return to the empirical implications of this assumption later.

In addition, the SSF faces a convex cost function, $C(\cdot)$ which is increasing in the input prices h and effort $\omega(\delta)$ (i.e non-price input related costs). Thus, the small farm's cost function is also affected by proximity to the MSF through its effect on non-price input related costs. Using the information above, we can summarise the farmer's problem as a choice of effort level, ω, in order to maximise profits, π as given below

$$\pi = p * f(x(\omega), L, n, z) - C(\omega(v+t), L, h) \quad (4)$$

Normalising output price to 1 and maximising with respect to ω yields the following first-order condition

$$f_x{}'(x(\omega), L, n, z) x_\omega{}'(\omega) = C_\omega{}'(\omega(v+t), L, h) \quad (5)$$

For notational simplicity, we can represent Equation 5 as follows:

$$f_x{}'(x(\omega), L, n, z) x_\omega{}'(\omega) = C_\omega{}'(\omega(\delta), L, h) \quad (6)$$

Equation 6 above implies that the farmer chooses a level of efforts, ω, such that the marginal benefit in terms of output exactly compensates for the marginal input-related costs. However, we are interested in the effect of proximity to a MSF on the input vector $x(\cdot)$. That is, we are interested in the sign of $dx(\omega)/dL$.

Proposition 1

The effect of proximity to a MSF on the small farm's input vector $x(\cdot)$ and output is mediated by how the MSF's activities affect input-related costs and generate knowledge spillovers.

Proof.

To obtain $dx(\omega)/dL$, we will totally differentiate the first order condition obtained in Equation 5 with respect to the variable of interest, L. Observe that $x(\omega)$ is an increasing function of ω. Hence, to show how $x(\omega)$ changes with respect to L, it is sufficient to show what happens to ω as L changes.

That is, we just want to show how the effort exerted by the small-scale farm changes as proximity to a MSF increases. From the first order condition, we know that

$$f_x{}'(x(\omega, L), n, z) x_\omega{}'(\omega) = C_\omega{}'(\omega(m), L, h).$$

Therefore, taking a total derivative with respect to l and solving for $d\omega/dL \equiv \omega_L$ gives the following:

$$f_x{}'(x(\omega), L, n, z) x_\omega{}'(\omega) = C_\omega{}'(\omega(m), L, h) \quad (7)$$

$$f_{xx}{}'(x(\omega), L, n, z)[x_\omega{}'(\omega)\omega_L + f_{xl}(x(\omega), L, n, z)] x_{\omega\omega}{}'(\omega) + f_x{}'(x(\omega), L, n, z) x_{\omega\omega}{}''(\omega)\omega_L = C_{\omega\omega(\delta)}{}''(\omega(\delta), L, h)\omega_L + C_{\omega L}{}'(\omega(\delta), L, h) \quad (8)$$

$$\frac{d\omega}{dL} = \omega_L \frac{f_{xL}(x(\omega), L, n, z) x_\omega{}'(\omega) - C_{\omega L}{}'(\omega(v+t), L, h)}{C_{\omega\omega(\delta)}{}''(\omega(\delta), L, h) - f_{xx}{}'(x(\omega), L, n, z) x_\omega{}'(\omega) - f_x{}'(x(\omega), L, n, z) x_{\omega\omega}{}''(\omega)}$$

Given that $f_x{}' x_\omega > 0$ and $f_{xx}{}' x_{\omega\omega} < 0$ by concavity and $C_{\omega\omega} > 0$ by convexity, the denominator is positive. Therefore, the sign of ω_L depends on the numerator which implies that it depends on the sign of $C_{\omega L}$, the cost effect and f_{xL} the learning effect.

As the proof shows, the precise direction of the effect depends on the sign of $f_{xL}\ (x(\omega), l, n, z)\ x_\omega{}'(\omega) - C_{\omega L}{}'(\omega(v+t), L, h)$ which implies that it depends on the sign of $C'_{\omega L}$, the cost effect and f_{xL}, the learning effect. Even though several possibilities could emerge, we consider three natural cases:

1. $f_{xl} > 0$ *and* $C'_{\omega l} < 0$. This is a case of pure positive spillovers where proximity to the MSF reduces input-related costs and induces knowledge and input quality spillovers unto the small farms.
2. $f_{xl} < 0$ *and* $C'_{\omega l} > 0$. This is pure negative spillover where the presence of the MSF increases transaction costs and also generates negative learning effect.
3. $f_{xl} = 0$ *and* $C'_{\omega l} = 0$. This is the neutral case where proximity to the MSF has no significant effects on the SSF. This is also possible if the two terms cancel each other out.[4]

Since we assume that proximity to MSF impacts the SSF's household utility through its effect on total income Y, the spillover effects on the profit of the SSF should translate to improved welfare through its effect on productivity and resultant income and poverty status. We explore proposition 1 using data from two Nigerian states that have recently experienced a rapid growth in MSFs.

4 DATA AND STUDY SAMPLE

The two data sources for this paper come from the Agricultural Policy Research in Africa (APRA) 2018 survey for Nigeria. This data set covers farms in two Nigerian states; Kaduna in north-west Nigeria and Ogun in south-west Nigeria. These states were purposively selected because of the significant steps they have taken in providing the necessary policy environment for the development of commercial agriculture. In each state, the largest LGA based on total LGA land size was selected from each of the state's three senatorial districts. In each LGA, a complete listing of all households controlling (owned, rented in, borrowed, etc.) or operating five hectares and above was collected using a household listing protocol (available upon request). LGAs consist of wards (administrative units within LGAs numbering between 9 and 12) and each ward contains several communities, which may be villages or towns. The listing exercise was carried out across all three selected LGAs in both Kaduna and Ogun states between October 2017 and March 2018. These listing exercises resulted in the listing of 9,361 MSF in Kaduna and 5,848 MSF in Ogun State (Muyanga *et al.* 2019). This listing data is our first main data source for all the information on the prevalence of MSFs in the LGA of a SSF.

The second data covers 1,078 SSFs and 1,031 MSFs randomly selected from sampling frames generated from the listing data. The data set is a cross-section and contains detailed information on household socio-economic characteristics including demographics, land holdings, assets and agricultural production and sales over the previous main agricultural season. We define SSFs as farmers who operate a total of less than 5ha of land. MSFs were defined as those who operate between 5ha and 50ha of land across crops. The number of MSFs in the LGA of a smallholder farmer is restricted to the number of MSFs in existence prior to the input use and production and sales data used in the empirical section. Since the listing data includes information on the year the MSF started, we restrict our analysis to the number of MSFs in a given LGA in the year prior to the main agricultural season for which the input and output decisions we study were collected. This guarantees that the study outcomes and interactions between SSFs and MSFs are being related to the prevalence of MSFs in the vicinity prior to those outcomes or interactions.

5 EMPRICAL ANALYSIS

From propostion 1, the main empirical specification to test our learning effect hypothesis is expressed in Equation 9, while Equation 10 tests our cost effect hypothesis

$$y_{ig} = \alpha + [f_{xl}(x(\omega), l, n, z)x'_{\omega}(\omega)]T_{ig} + \beta_1 X_{1g} + \beta_2 X_{2ig} + \beta_3 X_{3ih} + \mu_{ig} \quad (9)$$

$$y_{ig} = \alpha + [C'_{\omega L}(\omega(v+t), L, h)]P_{ig} + \beta_1 X_{1g} + \beta_2 X_{2ig} + \beta_3 X_{3ih} + \mu_{ig} \quad (10)$$

where y_{ig} is the outcome variable of interest for small plot i in local government area g.[5] The outcomes we consider in our estimations can be grouped into three broad categories: welfare outcomes, input use and output related outcomes. The input use variables we consider are the dichotomous use of improved seeds, inorganic fertiliser and agrochemical crop protectants and the log kilogram of each input used per hectare of land cultivated. The output related outcomes are crop yield, log crop income (in ₦) per hectare and the sale price per kilogram sold and a commercialisation index measured by the proportion of harvested output that is sold. The welfare measures we explore are total income and subjective poverty. Subjective poverty is a self-reported measure that asks respondents: 'How would you describe your household in general?' Responses that said the household was 'struggling' or 'unable' to meet household needs were coded as 'poor' while those that said the household was 'doing okay and able to meet their needs' were classified as 'non-poor.' In addition, we consider an objective measure of poverty, which is defined as 1 if the household's per capita income is below the international poverty line of US$1.90 per day and 0 otherwise. Using this measure of poverty, we compute a measure of poverty gap, which equals the difference between the household's daily per capita income and the US$1.90 poverty line if the household is poor and 0 otherwise. Poverty severity is then obtained by squaring the poverty gap and is used as an additional outcome variable. The poverty severity measure allows us to examine the severity of poverty among the poor (Foster, Greer and Thorbecke 1984).

The right-hand side variables include LGA characteristics X_{1g} that affect the decision of MSFs to locate in the LGA g of plot i, as well as other plot-specific (X_{2ig}) and household-level characteristics (X_{3ih}) while μ_{ig} is the error term. The parameter of interest here is $[f_{xl}(x(\omega),l,n,z)\ x'_{\omega}(\omega)]$ from proposition 1A, which is the measure of the direct effects of learning from a MSF while $[C'_{\omega L}(\omega(v+t),L,h)]$ measures the impact on y_{ig} of purchasing input from a MSF. However, due to unobservable factors such as ability or progressiveness that may influence SSFs to self-select into beneficial interactions with MSFs while simultaneously making those small farmers more likely to use particular inputs or have higher yields, our estimates of $[f_{xl}(x(\omega),l,n,z)\ x'_{\omega}(\omega)]$ and $[C'_{\omega L}(\omega(v+t),L,h)]$ are likely to be biased.

To be able to identify an unbiased estimate of our parameters of interest, we adopt a CFA as proposed by Imbens and Wooldridge (2007).[6] With the CFA, the generalised residuals from a first stage estimation of the determinants of interacting with MSFs is included in a second stage estimation of the effects of interacting with MSFs on SSF behaviour and outcomes. In all second stage estimations, P-values are estimated via bootstrapping at 500 repetitions to account for the fact that the generalised residual came from a first stage regression estimation and the errors are clustered at the household level. As in the traditional Instrumental Variable (IV)/Two Stage Least Squares (2SLS) approach, the CFA also requires at least one variable that is strongly correlated with a SSF's likelihood of interacting with a MSF but is uncorrelated with the unobserved factors that affect our outcome variables of interest (μ_{ig}) and thus appropriately excluded from (9) and (10). The estimates from this approach are more efficient although less robust than the IV estimator (Wooldridge 2015). The excludable instrument used in this analysis is the number of MSFs in a SSF's LGA. Conditional on accounting for factors that influence the emergence of MSFs and interactions with them, the coefficient on the number of MSFs should not be statistically different from zero. Accordingly, we argue that conditional on our rich set of LGA, household and plot control variables, the number of MSFs in a farmer's LGA should not affect the farmer's input use behaviour and farm outcomes except through the interactions necessary for our hypothesised spillover effects. These

LGA characteristics include the mean distance to an all-weather road, total area cultivated in the LGA, total population density and mean labour productivity in the LGA measured as the mean crop yield per labour day as well the mean average rainfall over the last ten years preceding the MSF listing census. The rainfall data was extracted from the Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) database.

Because we are using a cross section data set and not a panel, we cannot control for household time invariant unobserved factors. We attempt to address this limitation with a rich set of controls to capture the likely time invariant variables that could affect input use and welfare such as education, social capital and wealth. Farmer and household characteristics include age, gender, marital status, years of educational attainment and years of farming experience of the household head, household size and whether the household has any member engaged in non-farm activities, household land and livestock asset holdings (measured by the household's tropical livestock unit). We also control for whether the household has access to the government extension service. For plot characteristics, we control for whether the plot is owned or rented and whether the household has the land title to the plot. We also control for the plot size (in hectares), household distance to the plot (in kilometres), number of household members that worked on the plot in the last agricultural season, the soil type (clay, sandy or loamy) and the level of the parcel slope and terrace (flat, moderate terraced, moderate slope or steep slope).

To show that our exclusion restriction criterion is likely met and confirm that we have plausible reason to believe that we have appropriately accounted for enough factors to expect the coefficient on the number of MSFs to not statistically differ from zero, we also conduct a falsification-like test. This test shows that conditional on our LGA and farmer controls, the number of MSFs does not significantly affect our study outcomes on input use, productivity and welfare (see section 7 for the full details). In addition to the number of MSFs in a SSF's LGA, we also conduct our analysis using the share of the area in the LGA cultivated by MSFs and our results are almost identical.

In theory, the existence of positive spillovers will imply $f_{xl}(x(\omega),l,n,z)x'_{\omega}(\omega)>0$ and $C'_{\omega L}(\omega(v+t),L,h)<0$ while negative spillovers will imply that the converse is true in both cases. As mentioned above, for unbiased and consistent estimates of $f_{xl}(x(\omega),l,n,z)x'_{\omega}(\omega)$ and $C'_{\omega L}(\omega(v+t),L,h)$ we re-estimate Equations 9 and 10 using the two-step control function approach.

To do this, we first estimate a non-linear reduced form model of the endogenous variables (interaction with MSFs) on the instrument (i.e. the number of MSF in the LGA of the SSF) and a rich set of covariates. Then, we estimate the structural equation with the generalised residuals from the first stage non-linear estimation alongside the rich set of covariates included in the first stage. Specifically, obtaining the learning effect involves estimating the following conditional expectation of the outcome y_{ig} in Equation 11:

$$E\left(y_{ig}|Z_{ig},T_{ig}\right) = \alpha + \delta Z_{ig} + \beta_0 T_{ig} + E(u_1|Z_{ig},T_{ig}) \quad (11)$$

which implies that we must be able to estimate $E(u_{ig}|Z_{ig},T_{ig})$ where $Z_{ig}=(X_{ig}, \sum_i L_{ig})$ and $\sum_i L_{ig}$ is the number of MSFs in the LGA of farmer i . If Equation 10 holds:

$$T_{ig} = 1[\delta_0 \textstyle\sum_i L_{ig} + \beta_2 X_{2ig} + \beta_3 X_{3ih} + v_{ig} \geq 0] \quad (12)$$

Then $(u_{ig}, v_{ig}) \perp \sum_i L_{ig}$ and $E(u_{ig}|v_{ig}) = \rho v_{ig}$ and $v_{ig} \sim Normal(0,1)$ which implies that by iterated expectations:

$$E\left(u_{ig}|Z_{ig},T_{ig}\right) = E\left[E\left(u_{ig}|Z_{ig},v_{ig}\right)|Z_{ig},T_{ig}\right] = \rho E\left(v_{ig}|Z_{ig},T_{ig}\right) \quad (13)$$

Which gives:

$$E\left(u_{ig}|Z_{ig},T_{ig}\right) = \rho\left|T_{ig}\left[\frac{\phi(\delta_0 \sum_i L_{ig})}{\Phi(\delta_0 \sum_i L_{ig})}\right] - \left(1-T_{ig}\right)\left[-\frac{\phi(\delta_0 \sum_i L_{ig})}{\Phi(\delta_0 \sum_i L_{ig})}\right]\right| \quad (14)$$

where $\phi(\cdot)/\Phi(\cdot)$ is the inverse mills ratio. The estimate of δ_0 that is $(\delta_0)\hat{}$ can then be obtained with a probit estimation. Using $(\delta_0)\hat{}$, we can generate the generalised residual as follows:

$$\widehat{v_{ig}} = T_{ig}\left[\frac{\phi(\widehat{\delta_0}\{\sum_i L_{ig})}{\Phi(\widehat{\delta_0}\{\sum_i L_{ig})}\right] - \left(1-T_{ig}\right)\left[-\frac{\phi(\widehat{\delta_0} \sum_i L_{ig})}{\Phi(\widehat{\delta_0} \sum_i L_{ig})}\right] \quad (15)$$

We then include $(v_{ig})\hat{}$ as a regressor in Equation 14. This yields a structural equation of the form:

$$y_{ig} = \alpha + [f_{xl}(x(\omega),l,n,z)x'_{\omega}(\omega)]T_{ig} + \beta_1 X_{1g} + \beta_2 X_{2ig} + \beta_3 X_{3ih} + \rho\hat{v}_{ig} + \mu_{ig} \quad (16)$$

Where $[f_{xl}(x(\omega),l,n,z)x'_{\omega}(\omega)]$ is the learning effect parameter (i.e. the parameter which captures how knowledge is transferred from MSFs to SSFs) and $\hat{v}_{ig}$ is the generalised residuals. In both equations, X_{1g}, X_{2ig} and X_{3ih} remain as earlier defined (i.e community characteristics that affect the decision of MSF to locate in the LGA g, plot-specific factors and household-level characteristics respectively). A straightforward test of $\rho=0$ then tells us about endogeneity in the estimated model. We estimate Equation 16 separately for the learning and cost effects and for the different outcomes of yield, crop income and sale price as well as input use decisions regarding improved seed use, inorganic and organic fertiliser as well as chemical protectants using linear and non-linear probit techniques as appropriate.

6 RESULTS

We find evidence of significant interaction between small-scale farmers and medium-scale farmers in our sample (Table 6.1). Approximately 30 per cent of the small-scale farmers reported to have received training on farm activities directly from a MSF. A similar percentage reported to have purchased inputs from a MSF and or sold their crop output to a MSF. These suggest the existence of important channels for knowledge and cost reduction spillovers. Government Agricultural extension in Nigeria is notably weak with a poor extension agent to farmer ratio of over 5,000 farm families to one agent in 2018 (Akinfenwa 2018). Studies have shown that extension agents are often not only ill-equipped to reach the many farmers allocated to them but have limited opportunities for training and thus lack correct information about many modern technologies (Ragasa and Mazunda 2018). This creates ample room for improved productivity through knowledge transfer from commercial MSFs to SSFs around them. Low profitability of modern input use due to high transactions cost has also been documented in Nigeria (Liverpool-Tasie *et al.* 2017; Liverpool-Tasie 2016; Takeshima and Liverpool-Tasie 2015). Thus, the opportunity to purchase inputs from MSFs could significantly reduce the transportation costs for SSFs. In addition, if medium-scale farmers have the ability to secure higher quality inputs (e.g. via the ability to test the quality of inputs, incentivise input suppliers to provide good quality inputs for a guaranteed market and/or better storage for inputs) then SSFs can also enjoy an input quality benefit from purchasing inputs from MSFs.

Table 6.1: Interactions with MSFs

Small-scale farmer:	All crops	Cereals	Roots and tubers	Other crops
Purchased inputs from a MSF	27%	30%	18%	21%
Received training on farm activities from a MSF	28%	25%	30%	41%
Sold farm output to MSF	28%	30%	24%	18%

Source: Author's calculation

Table 6.2: Summary statistics of key outcome variables

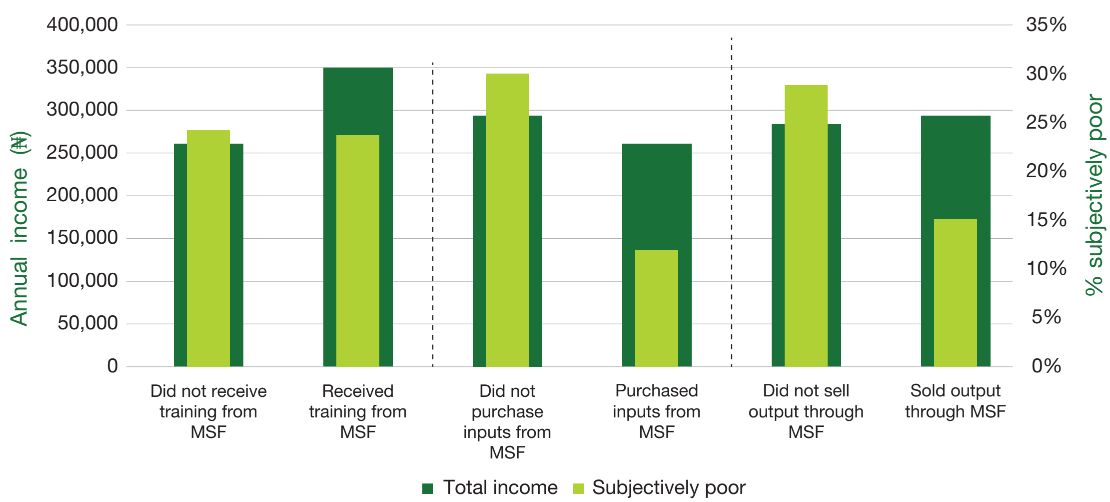
	Mean	Median	SD
Gross total income (₦)	286,030	150,000	460,284
Gross crop income (₦)	198,982	100,000	343,538
Share of households below income poverty line	0.39	0	0.49
Share of household that reported to be struggling to meet basic needs (subjective poverty)	0.25	0	0.43
Poverty gap	0.24	0	0.34
Poverty severity	19	0	0.35
Sale price per kg	147.26	90.00	243.45
Share of output sold	0.66	0.80	0.38
Used improved seed (1/0)	0.24	0	0.43
Used chemical fertiliser (1/0)	0.53	1	0.50
Used agrochemicals (1/0)	0.38	0	0.49
Seeding rate for improved seed (kg/ha)	53.25	15.15	126.08
Kilograms of fertiliser used/ha	3.28	2.7	2.48
Kilograms of chemicals used/ha	5.59	4.00	5.43

Source: Author's calculation

The mean annual total income in our study sample is ₦288, 000 (about US$800)[7] with about 70 per cent of it accounted for by crop income. About 40 per cent of the study sample are below the income poverty line at US$1.09 a day though a smaller share (25 per cent) reported struggling to meet their family needs in the last year. Irrespective of the type of interaction, SSFs in our sample that interacted with a medium-scale farm are less likely to have reported experiencing challenges in meeting their households' needs in the last year (Figure 6.1). Figure 6.1 also shows farmers that received training from or sold to MSFs tend to have higher incomes compared to those who do not. However, we do not see any difference in the share of farmers that use modern inputs among those that received training, sold to or purchased inputs from MSFs compared to those who did not (Figure 6.2). This might imply that the mechanism through which SSF welfare is improved through increased interaction with MSFs might lie outside of expanded use of modern inputs. Since these descriptive results do not control for the myriad of other factors that could explain welfare (income and probability of being in poverty) or input use, we confirm this with the empirical results from our CFA results presented in Tables 6.3-6.6.

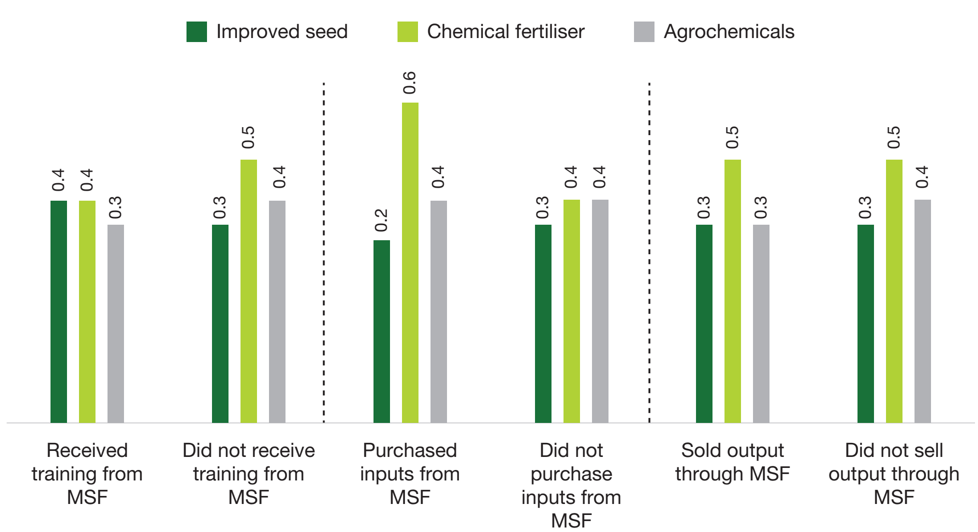
In line with the logical framework in Figure 6.3, we start with the basic hypothesis about whether interacting with MSFs is welfare-enhancing for SSFs. Then, we try to identify the mechanisms through which any observed welfare effects materialise, drawing from our theoretical framework. Table 6.3 presents the first stage regressions on the determinants of SSF interaction with MSFs. These are the marginal effects from the non-linear probit results of the determinants of SSF interaction with MSFs. As expected, it confirms that

Figure 6.1: Differences in income and subjective poverty by interaction with MSFs



Source: Author's calculation

Figure 6.2: Input use among small-scale farmers by interaction with MSFs



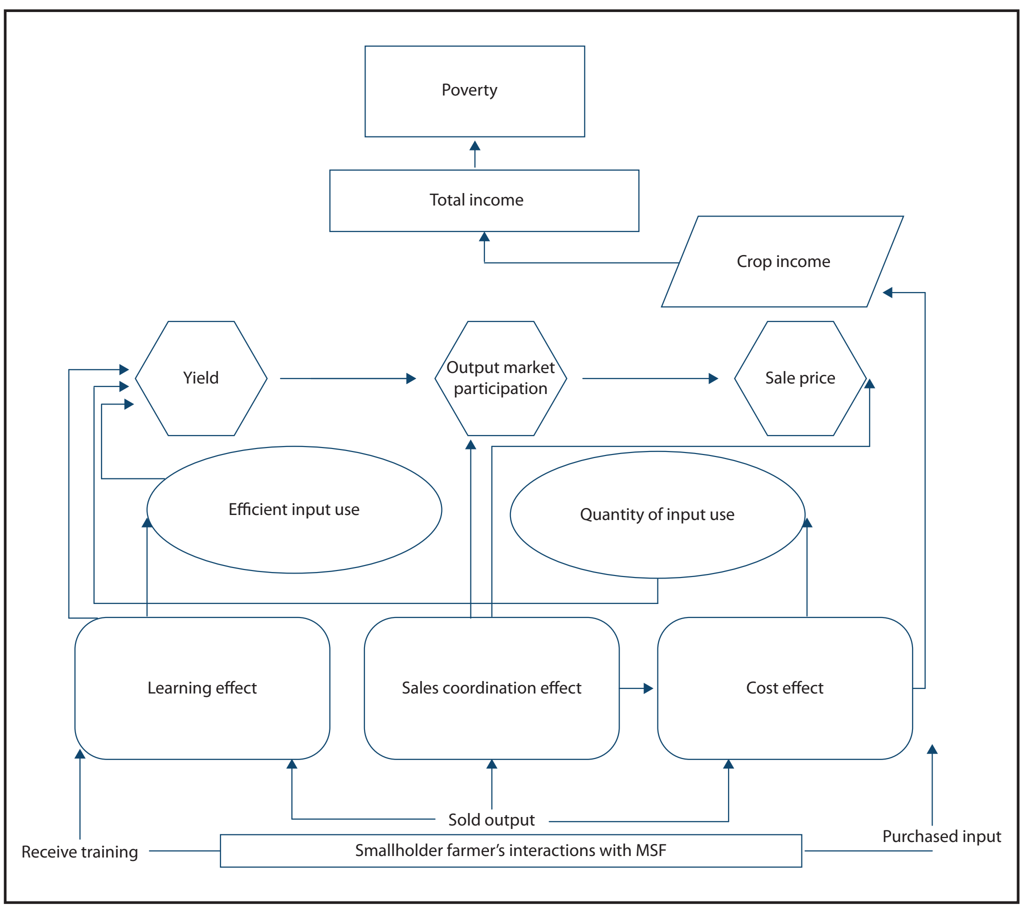
Source: Author's calculation

increased presence of MSFs in a SSF's LGA increases the likelihood of their interaction. The coefficients on the number of MSFs in the local government are highly significant at 1 per cent, 5 per cent and 10 per cent[8] for receiving training, selling output to and purchasing inputs from MSFs respectively.

Table 6.4 presents the CFA results for our six welfare outcomes; crop income, total income,[9] household income poverty status (1/0), poverty gap (distance of total income per capita from the income poverty line), poverty severity (squared poverty gap) and subjective poverty status equal to 1 if household responded to be struggling or unable to meet household needs in the last year. The results indicate that receiving training from a MSF is associated with large, statistically significant welfare effects for small farmers. All other things being held constant, total and crop incomes will increase by 94 per cent and 109 per cent respectively for a small farmer who received training from a MSF. This higher income is associated with a statistically significantly lower probability of being income poor (by 11.6 percentage points) as well as a smaller poverty gap and severity for the poor. We find similar results for SSFs who purchased inputs from or sold outputs to MSFs. These interactions are associated with higher crop and total income as well as lower poverty incidence, poverty gap and poverty severity at household level. Apart from the impact of sales to MSFs on income poverty (significant at 10 per cent), all of the welfare impacts are statistically significant at 5 per cent or less and large in magnitude. In each model, the significance of the generalised residuals from the first stage reveals the endogeneity of the training variable, but is also correct for it (Vella 1993; Rivers and Vuong 1988; Smith and Blundell 1986).[10]

To identify drivers of the observed welfare gains and test for evidence of cost and knowledge spillover on SSFs, we explore the impact of interacting with MSFs on SSF modern input use, productivity and commercialisation. Tables 6.5 and 6.6 present these results. The only positive effect of interacting with MSFs on modern input use comes from receiving training. SSFs who received training from a MSF are 3.9 percentage points more likely to use improved seed and with higher seeding intensity. However, they are no more likely (than SSFs without such interaction) to use fertilisers or crop protectants. This might reflect the role that training can play in encouraging

Figure 6.3: Logical framework for small-scale farmer interactions with MSFs



Source: Author's calculation

the adoption of modern technologies that are not commonly used (only 24 per cent of the SSFs sample are using improved seeds) compared to fertiliser that is currently already being used by 55 per cent of SSFs in the sample (see Table 6.2).

We do not find any evidence of cost spillovers on input use. Rather we find that SSFs who purchase inputs from MSFs are significantly less likely to purchase chemical fertilisers and use it with lower intensity compared to those who do not. They are no more likely to use improved seed or crop protectants. Though this result is consistent with Lay, Nolte and Sipangule (2018) who find negative spillover effects of large farms on SSF fertiliser use, it is still surprising. If purchasing inputs from MSFs guarantees a higher quality for inputs, then SSFs might not have to use excessive amounts of fertiliser to achieve desired yields because of uncertainty about product quality (Khor and Zeller 2016). This might explain lower fertiliser intensity for these farmers compared to their counterparts purchasing from the open market. With increasing concerns about the overuse of chemicals in agricultural production, the lower probability of chemical fertiliser use might reflect negative messages passed on to SSFs from MSFs about chemical overuse or be requirements imposed by these farms on SSFs as suggested earlier.[11] Farmers who sell to MSFs are statistically significantly less likely to use crop protectants and at lower levels compared to those who don't sell to MSFs. The coefficient on chemical fertiliser use is negative but insignificant.[12]

Though only the provision of training by MSFs seems to promote SSF modern input use (improved seed), both receiving training and input purchase are consistently associated with statistically significantly higher yields (Table 6.6). This implies that the positive effects of MSFs on SSFs' productivity and welfare is largely not mediated through cost spillovers that expand modern input use. This yield improvement might occur through improved efficiency of modern input use from higher quality and/or through improved crop management practices through training. We also find that farmers who received training from MSFs and/or purchased input from or sold output through MSFs receive a higher output price for their crops. Receiving training from a MSF is associated with receiving a sales price about ₦1.07 higher per kg sold. Purchasing inputs from and selling output to a MSF are associated with about ₦0.09 and ₦2.31 higher price per kg respectively.

Surprisingly, we find limited evidence of interacting with MSFs on the share of output sold by SSFs. This is consistent for all interactions. The average SSF in our sample sells almost 70 per cent of their output. This high rate of commercialisation might explain why we do not see much impact. However, the higher price associated with being trained by a MSF or selling to them definitely indicates some positive commercialisation opportunities from MSFs.

Table 6.3: First stage results of the determinants of SSF interactions with MSFs

Variables	Interaction with medium-scale farm		
	Purchased input	Received training	Sold output
Number of MSFs in LGA	0.004*	0.010***	0.005**
	(0.002)	(0.002)	(0.002)
No. of household members who worked on plot	-0.021**	-0.014	0.031***
	(0.010)	(0.011)	(0.011)
Soil type is clay (1/0)	0.021	-0.411***	0.157
	(0.108)	(0.113)	(0.098)
Soil type is loamy (1/0)	0.057	-0.278***	0.189***
	(0.063)	(0.089)	(0.054)
Moderate terraced slope (1/0)	0.005	-0.188***	-0.003
	(0.054)	(0.037)	(0.058)
Moderate slope (1/0)	0.013	-0.062*	-0.028
	(0.042)	(0.037)	(0.040)
Steep parcel slope (1/0)	0.470***	0.109	0.444***
	(0.127)	(0.156)	(0.136)
The farmer has land title for this plot	0.021	0.159**	-0.272***
	(0.063)	(0.073)	(0.024)
Total livestock unit	0.002	-0.136***	0.076*
	(0.039)	(0.043)	(0.041)
Plot size (ha)	0.001	-0.004	-0.008
	(0.003)	(0.003)	(0.005)
Distance to plot (km)	-0.004	0.007	-0.025***
	(0.005)	(0.005)	(0.006)
Years of experience in farming	-0.004**	-0.004**	-0.005***
	(0.002)	(0.002)	(0.002)
Head married (1/0)	-0.009	-0.020	-0.011
	(0.016)	(0.017)	(0.018)
Head is male (1/0)	0.215***	0.050	-0.011
	(0.042)	(0.065)	(0.076)
Head education in years	0.005**	0.007***	0.003
	(0.002)	(0.002)	(0.002)
Head age in years	0.003*	0.002	0.005***
	(0.002)	(0.001)	(0.002)
Household size	-0.005	-0.004	-0.009*
	(0.005)	(0.005)	(0.005)
Household has non-agricultural worker (1/0)	-0.107***	-0.209***	0.068*
	(0.028)	(0.023)	(0.035)
Mean distance to all-weather road in LGA (km)	-0.003	-0.055	-0.138*
	(0.074)	(0.071)	(0.076)
Mean LGA productivity/ha	-0.000	0.000	0.000
	(0.000)	(0.000)	(0.000)
Total area cultivated in LGA	0.050	0.431	0.619
	(0.378)	(0.355)	(0.387)
LGA population density	0.505	2.263	4.033
	(2.418)	(2.227)	(2.465)
Mean annual rainfall in LGA over the period 2007–2017	-0.002	0.001	-0.003*
	(0.002)	(0.002)	(0.002)
Ogun State [dummy variable] (1/0)	-0.234	0.366**	0.249
	(0.193)	(0.180)	(0.176)
Number of observations	1,709	1,687	1,687

Note: Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Table 6.4: Impacts of interaction with MSFs on SSF welfare outcomes

	Received training from MSF (1/0)	Residuals	Purchased input from MSF (1/0)	Residuals	Sold output through MSF (1/0)	Residuals
Subjective poverty incidence	0.248	-0.167*	-0.123***	-0.103	-0.468**	0.220*
	(0.160)	(0.096)	(0.023)	(0.218)	(0.218)	(0.131)
Household is income poor (1/0)	-0.116***	0.109	-0.084**	0.001	-0.554*	0.315*
	(0.032)	(0.145)	(0.034)	(0.233)	(0.292)	(0.176)
Poverty gap	-0.068***	-0.002	-0.094***	0.008	-0.420***	0.220***
	(0.025)	(0.084)	(0.026)	(0.104)	(0.127)	(0.077)
Poverty severity	-0.050**	-0.024	-0.100***	0.031	-0.437***	0.228***
	(0.023)	(0.079)	(0.023)	(0.095)	(0.121)	(0.073)
Inverse-hyperbolic sine of total income (₦)	0.663**	0.399	4.756**	-2.005*	7.832***	-4.246***
	(0.271)	(1.360)	(1.961)	(1.121)	(2.479)	(1.464)
Inverse-hyperbolic sine of crop income (₦)	0.739**	0.316	8.773***	-4.054***	11.172***	-5.807***
	(0.323)	(1.310)	(2.207)	(1.254)	(2.976)	(1.794)

Note: Bootstrapped standard errors clustered at household level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All estimations include all the control variables used in the first stage.

Table 6.5: Impacts of interaction with MSFs on input use among SSFs

Panel A						
Variables	**Used improved seeds (1/0)**		**Used fertiliser (1/0)**		**Used crop protectants (1/0)**	
	(1)	(2)	(3)	(4)	(5)	(6)
Received training from MSF (1/0)	0.039*		0.023		0.025	
	(0.024)		(0.022)		(0.024)	
Learning effect residuals	-0.013		0.034		-0.117	
Purchased input from MSF (1/0)		-0.214		-0.643**		0.289
		(0.236)		(0.276)		(0.359)
Cost effect residuals		0.103		0.459***		-0.204
Observations	1,539	1,561	1,671	1,693	1,669	1,691
Panel B						
	Quantity of improved seed used per ha		**Quantity of fertiliser used per ha**		**Quantity of crop protectants used per ha**	
	(1)	(2)	(3)	(4)	(5)	(6)
Received training from MSF (1/0)	25.434*		-3.252		7.047	
	(14.246)		(5.870)		(4.910)	
Learning effect residuals	-2.640		2.066		-3.637	
	(58.501)		(3.570)			-0.951
Purchased input from MSF (1/0)		-134.129		-23.975***		(9.311)
		(120.884)		(7.481)		0.230
Cost effect residuals		71.097		15.183***		(5.647)
Observations	1,557	1,579	1,687	1,709	1,684	1,706

Note: Bootstrapped standard errors clustered at household level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All estimations include all the control variables used in the first stage

Table 6.6: Yield and commercialisation impacts of small-scale farmer interaction with MSFs

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Variables	**Yield/ha**			**Sale price/kg**			**Commercialisation level**		
Received training from MSF (1/0)	0.156**			1.069***			0.134		
	(0.068)			(0.404)			(0.107)		
Learning effect residuals	-0.080**			-0.501**			-0.081		
	(0.041)			(0.248)			(0.063)		
Purchased input from MSF (1/0)		0.016**			0.095*			-0.198	
		(0.008)			(0.054)			(0.129)	
Cost effect residuals		-0.028			-0.303			0.116	
		(0.048)			(0.282)			(0.079)	
Sold output through MSF (1/0)			0.391***			2.307***			0.223
			(0.093)			(0.513)			(0.140)
Coordination effect residuals			-0.232***			-1.327***			-0.134
			(0.057)			(0.311)			(0.086)
Observations	1,660	1,691	1,660	1,364	1,382	1,363	1,382	1,382	1,363

Note: Bootstrapped standard errors clustered at household level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All estimations include all the control variables used in the first stage

7 ROBUSTNESS CHECKS AND ADDITIONAL CONSIDERATIONS

7.1 Testing the exclusion restriction

This study finds strong evidence of positive welfare impacts for SSFs that engage with MSFs in their communities. The significance of the generalised results in some of the CFA results in Tables 6.4-6.6 reveals that the interactions between SSFs and MSFs are endogenous for many of the outcome variables. As indicated earlier, our identification strategy is based on the number of MSFs in a SSF's LGA being an appropriate instrument. While this instrument is strongly correlated with our endogenous variable (interaction with a MSF), it is not usually possible to test if an instrument satisfies the exclusion restriction. In our model, we argue that our instrument satisfies the exclusion restriction. Conditional on the rich set of farmer and LGA characteristics (such as higher agricultural potential, better input markets, infrastructure, market access) that might be correlated with both the choice of location of the MSF (and farmers' interaction with them) and SSF input use, productivity and welfare, the number of MSFs in the LGA of a smallholder farm shouldn't matter for input use decisions and farm outcomes. Thus, learning and cost-reduction channels are left as the only paths via which MSFs can affect SSF outcomes and behaviour.

To confirm this, we estimate Equation 17

$$y_{ig} = \alpha + \beta_0 \sum_i L_{ig} + \beta_1 X_{1g} + \beta_2 X_{2ig} + \beta_3 X_{3ih} + \mu_{ig} \quad (17)$$

Where y_{ig}, X_{1ig}, X_{2ig} and $X_{(3ih)}$ are all as earlier defined and $\sum_i L_{ig}$ is the number of MSFs in a LGA g. Conditional on the LGA-specific characteristics, X_{1ig}, that might affect the number of MSFs $\sum_i L_{ig}$ in the LGA g of plot i, as well as other plot and household-level characteristics, we would expect β_0=0. Thus, by estimating Equation 17, we

Table 7.1: Exclusion restriction plausibility test results for all study outcomes

Variables	(1) Subjective poverty incidence	(2) Household is income poor	(3) Poverty gap	(4) Poverty severity
Number of MSFs	-0.001	0.000	-0.001	-0.001
	(0.002)	(0.002)	(0.002)	(0.002)
Observations	1,754	1,765	1,765	1,765
	(5) Crop Income	**(6) Total Income**	**(7) Non-farm Income**	**(8) Yield/ha**
Number of MSF	-0.004	0.017	0.007	0.001
	(0.006)	(0.020)	(0.053)	(0.001)
Observations	1,622	1,747	1,747	1,622
	(9) Sale Price	**(10) Commercialisation**	**(11) Fertiliser Use**	**(12) Improved Seed (0/1)**
Number of MSF	0.010	-0.000	-0.001	-0.001
	(0.007)	(0.002)	(0.002)	(0.003)
Observations	1,442	1,747	1,626	1,618
	(13) Used Agrochemical	**(14) Improved seed (Kg/ha)**	**(15) Fertiliser (WKg/ha)**	**(16) Agrochemical (Kg/ha)**
Number of MSF	-0.001	-1.029	-0.048	-0.081
	(0.005)	(1.502)	(0.079)	(0.109)
Observations	1,772	1,629	1,774	1,771

Note: Standard errors in parentheses, *** p<0.01, ** p<0.05, * p<0.1. All estimations include all the control variables used in the first stage.

argue that the absence of a direct effect of the number of MSFs on farmer behaviour is a likely indication that our exclusion restriction for the instrumental variable $\sum_i L_{ig}$ is met. Table 7.1 presents the results of our estimation of Equation 17. The estimated coefficients from Equation 17 are consistently statistically zero. These findings validate the assumption that exclusion restriction likely holds for the number of MSFs conditional on the LGA variables that may affect the number of MSFs located there. Although we include total cultivated area in the LGA as a control, we also explore an alternative instrument, using the number of MSFs as a share of the total area of land cultivated in the LGA.[13]

7.2 Extent of interaction

We consistently find significant positive productivity and welfare impacts of small farmer interaction with MSFs. While the higher yields associated with interacting with MSFs are consistent across interactions, it is not clear if this is driven solely by the particular interaction in question or if it is partly driven by other interactions that those SSFs might be simultaneously engaged in with MSFs. In a systematic evidence synthesis, Liverpool-Tasie *et al*. (2020) finds that in addition to serving as a marketing channel for small farmers, economic agents in the midstream of food value chains across Asia and Africa (such as wholesalers and agro-processors) are increasingly offering SSFs complementary services such as training and inputs. Providing these complementary services is presumably mutually beneficial as they ensure that they get the quantity and quality of products to meet their needs for processing and/or sale further down the value chain. They also find that the provision of these additional services is positively correlated with the probability that an interaction between a small farmer and a small and medium-sized enterprise (SME) in the midstream of the food value chain yielded a positive outcome for the smallholder.

To explore the extent to which MSFs might be playing similar roles as these SMEs and to confirm if the multiplicity of interactions is important for the observed welfare gains to small farmers, we explore the extent to which MSFs simultaneously provide training, input purchase and output sale opportunities to SSFs. Then, we check if this increased intensity of interaction is necessary for consistent positive welfare and productivity gains. Table 7.2 shows that while majority of the SSFs that interact with MSFs tend to engage with them in only one way (either purchasing an input from them or being trained by them or selling output to them), a significant share engage with MSFs in more than one way. Forty-three per cent engage in at least two different interactions while about 15 per cent engage in all of the three activities we explored. This indicates that there may be complementary service provisions by MSFs to SSFs around them and/or that there are opportunities for the combined effect of access to different inputs or complementary services and output market access.

Tables 7.3 and 7.4 present the results of the productivity and welfare impacts of more intense interactions with MSFs. Again, we apply the CFA and consider three measures of intensity; first the case when a SSFs has only one interaction, second, two or more interactions and third, the number of interactions with a MSF that a small farmer has. Table 7.3 presents the first stage results of the CFA conducted via a probit model for the probability of having only one interaction or two or more interactions. The first stage for the number of interactions is a Poisson model to account for the fact that our outcome is a count variable with a few numbers of potential outcomes (a maximum of three). We confirm (Table 7.3) that the number of interactions and having at least two interactions are all statistically significantly correlated (at 5 per cent or less) with the number of MSFs in a SSF's LGA. The first stage regression reveals that the relationship between only having one kind of interaction with a MSF is not significantly correlated with the number of MSFs. While this precludes us making any causal claims, we still explore the correlations between having only one interaction with a MSF and our study outcomes and see if that differs from the impact of those who have multiple interactions.[14]

Table 7.4 clearly reveals that higher number of interactions between a small farmer and a MSF is more consistently associated with positive productivity and

Table 7.2: Extent of interaction between SSFs and MSFs

SSF reported	Total sample
Only one interaction (conditional on at least one)	58%
Only two interactions (conditional on at least one)	27%
At least two interactions (conditional on at least one)	43%
All three interactions (conditional on at least one)	15%
Average number of interactions (conditional on at least one)	1.6

Source: Author's calculations

welfare impacts. Having one more interaction reduces a SSF's probability of being in income poverty by about 9 percentage points. A farmer who has at least two types of interaction with MSFs is 62 percentage points less likely to have reported having struggled to meet their household needs.

Similarly, while a household with only one interaction does not record having higher yield or receiving a higher sales price nor recording a higher crop or total income, farmers with more interactions tend to have higher crop and total incomes, sales price and yields. These positive impacts are all statistically significant and large in magnitude. We do not find any evidence of expanded modern input use or levels from engaging with MSFs in multiple ways. The limited evidence of multiple interactions on input use is to reduce the probability and/or intensity of modern input use. This confirms the earlier finding that the productivity impacts from engaging with SSFs is likely mediated through improved management practices and access to better quality inputs rather than promoting more modern input use. The welfare impacts occur through improved yields and sales price enabling small-scale farmers to enjoy higher crop incomes and lower probability of struggling to meet household needs.

Similarly, while a household with only one interaction does not record having higher yield or receiving a higher sales price nor recording a higher crop or total income, farmers with more interactions tend to have higher crop and total incomes, sales price and yields. These positive impacts are all statistically significant and large in magnitude. We do not find any evidence

Table 7.3: First stage results of the determinants of the intensity of SSFs interactions with MSFs

Variables	(1) Number of interactions	(2) Two or more interactions	(3) Only one interaction
Number of MSFs	0.012***	0.005***	0.002
	(0.004)	(0.002)	(0.321)
Other controls	Y	Y	Y
Observations	1,774	1,743	1,774

Note: Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All estimations include all the control variables used in the first stage

Table 7.4: Welfare impacts of multiple interactions between MSFs and SSFs

Panel A	Household is income poor (=1)			Poverty gap			Poverty severity		
Only one interaction	-0.008			-0.004			0.004		
	(0.032)			(0.023)			(0.021)		
Two or more interactions		-0.088**			-0.461**			-0.468**	
		(0.037)			(0.218)			(0.184)	
Number of interactions			-0.048***			-0.045***			-0.043***
			(0.016)			(0.012)			(0.011)
Observations	1,774	1774	1,743	1,774	1,743	1,774	1,774	1,774	1,743
	Total income			**Crop income**			**Subjective poverty incidence**		
Only one interaction	-0.125			-0.206			0.048		
	(0.256)			(0.274)			(0.02)		
Two or more Interactions		0.587***			7.037**			-0.620***	
		(0.130)			(2.975)			(0.20)	
Number of interactions			6.558***			9.374***			-0.057***
			(1.763)			9.374***			-0.057***
Observation	1,774	1,743	1,774	9.374***	1,743	1,774	1,763	1,732	1,732

Note: Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All estimations include all the control variables used in the first stage.

of expanded modern input use or levels from engaging with MSFs in multiple ways. The limited evidence of multiple interactions on input use is to reduce the probability and/or intensity of modern input use. This confirms the earlier finding that the productivity impacts from engaging with SSFs is likely mediated through improved management practices and access to better quality inputs rather than promoting more modern input use. The welfare impacts occur through improved yields and sales price enabling small-scale farmers to enjoy higher crop incomes and lower probability of struggling to meet household needs.

Table 7.5: Yield, commercialisation and input use impacts of multiple interactions between SSFs and MSFs

Variables	Yield/ha			Sale price/kg			Commercialisation		
Only one interaction	-0.013			-0.050			0.016		
	(0.009)			(0.057)			(0.013)		
Number of interactions		0.164*			1.289**			0.001	
		(0.092)			(0.556)			(0.005)	
Two or more Interactions			0.196***			1.203***			-0.194
			(0.068)			(0.434)			(0.125)
Observations	1,747	1,747	1,747	1,430	1,430	1,422		1,430	1,422
Variables	**Improved seed use (1/0)**			**Fertiliser use (1/0)**			**Crop protectant use (1/0)**		
Only one interaction	0.053***			-0.016			-0.030		
	(0.019)			(0.019)			(0.024)		
Number of interactions		0.009			0.015			-0.020*	
		(0.009)			(0.010)			(0.011)	
Two or more Interactions			-0.076			-0.435**			0.152
			(0.164)			(0.178)			(0.194)
Observations	1,809	1,747	1,725	1,820	1,758	1,727	1,818	1,756	1,725
Variables	**kg of improved seed used/ ha**			**kg of fertiliser used/ha**			**kg of crop protectant used/ha**		
Only one interaction	13.591			0.427			-1.291**		
	(10.641)			(0.952)			(0.568)		
Number of interactions		-259.057*			6.765			1.594	
		(156.359)			(8.187)			(5.513)	
Two or more Interactions			-8.390			-22.624***			-7.127
			(14.771)			(6.810)			(5.929)
Observations	1,598	1,629	1,619	1,743	1,774	1,763	1,740	1,771	1,760

Note: Bootstrapped standard errors clustered at household level in parentheses. *** p<0.01, ** p<0.05, * p<0.1. All estimations include all the control variables used in the first stage.

8 CONCLUSIONS

The last decade has seen a rapid rise in the number of MSFs (and share of land cultivated by them) in sub-Saharan Africa. While these commercialised farms are a potential mechanism to increase food production to meet Africa's rapidly growing population, there is limited empirical evidence on the myriad of ways through which this could happen. Beyond their own production, MSFs could support expanded food production and other dimensions of the structural transformation process if they also increase the productivity, commercialisation and ultimate income and welfare of SSFs around them. This could occur through increased access to input and output markets, knowledge and employment. On the other hand, their presence could compete with SSFs for land, limited modern inputs and poor government extension services. Ultimately, the empirical evidence on the impacts of the recent rapid growth of MSFs on small producers around them remains extremely limited.

Consequently, this paper examines if MSFs in Nigeria have an impact on the farming behaviour and welfare of SSFs in their vicinity. We find strong evidence of positive welfare impacts for SSFs that engage with MSFs in their communities. For Nigeria, knowledge spillovers from actual training is a key driver of farmer productivity and ultimate welfare. This appears to be partly through some impacts on modern input use (largely improved seed), but likely more through improved agricultural practices. While purchasing inputs from MSFs does not increase modern input use, it is still associated with higher yields, crop income and lower probability of income and subjective poverty. We find that the opportunity to sell to MSFs is a very important source of improved welfare in our study sample. It enables SSFs to receive higher prices, crop and total incomes and thus experience lower probability of being poor (and lower poverty gap and severity). We also find that having more than one interaction with a MSF (e.g. the ability to sell to them while also receiving training or purchasing inputs) is important to guarantee the improved welfare for small-scale farmers.

Our findings suggest that in areas where significant interactions between SSFs and MSFs can take place (to link these SSFs to training as well as output markets and high-quality inputs); there are likely benefits from government and/or donor support of these larger farms. With such poorly functioning government extension services and long-standing issues about input quality, leveraging on MSFs to facilitate the diffusion of new technologies could be extremely beneficial.

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ENDNOTES

1 We find that even when we expand the definition to 5ha to 100ha as was done in Jayne *et al*. (2016), over 95% of our households were between 5ha and 50ha and thus have used the latter so our work is comparable to both the literature using 5ha to 100ha (Jayne *et al*. 2016) and those using 5ha to 50ha such as Anseeuw *et al*. (2016).

2 Because our input use and crop yield determination occurs before our sales outcome (though through the effect of the number of MSFs in a farmer's vicinity in the previous farming year it is also possible that farmers who use higher inputs and have higher yields sold to MSFs), we focus more on the welfare effects of sales coordination.

3 In our study, approximately 27 per cent of all smallholder farms reported purchasing inputs from a medium-scale farm.

4 These three cases are not exhaustive, as mentioned, but give a general sense. Ultimately, the point remains that the net effect depends on whether the positives outweigh the negatives and vice versa.

5 Apart from the income and poverty outcomes, all study outcomes are at the plot level.

6 It should be noted that the objective of this paper is to isolate the spillover effect that can be attributed to interacting with MSFs. Thus, we acknowledge that this approach does not speak to how things will change subsequent to future changes to access to MSFs.

7 We use the exchange rate of ₦360 = US$1 that was prevalent in 2017.

8 Technically purchasing input is significant at 6 per cent.

9 Total income in this study is the sum of incomes from all documented sources namely, non-farm income including regular and casual income, remittances and gifts as well as farm income from crop and livestock sales.

10 For all estimations, the coefficients on the generalised residuals for the CFA analysis are presented. However, when we fail to reject exogeneity (the coefficient on the generalised residual is not significantly different from zero), the coefficient on the Ordinary Least Squares model is reported.

11 This would particularly be the case if farmers tend to engage in multiple interactions with MSFs such as selling output to MSFs and also buying inputs from them or receiving training from them on input use and or other agricultural practices.

12 We only focus on the sales and welfare effects of selling to MSFs as the input use decision occurs before the sale interaction.

13 These results are available upon request.

14 We expect that the endogeneity of the interaction variable to cause our estimates on input use and welfare outcomes to be upwardly biased and thus likely the upper bounds of any effect. Our results are largely insignificant indicating that they are an appropriate baseline confirming the broader findings of limited effects.

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