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The agricultural mechanization in Africa: micro-level analysis of state, drivers and effects

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Abstract

This paper examines the state, drivers and, consequently, the impacts of agricultural mechanization in eleven countries in Africa. Using representative multistage stratified household survey data and robust analytical approaches, findings show light hand-held tools and equipment remain the main type of machinery in most countries – about 48% of the sampled households have access to light machinery compared to 35% that have access to animal-powered machinery, and only about 18% that use tractor-powered machinery. Significant drivers of agricultural mechanization include the size of the household, gender of the household head, participation in off-farm economic activities, distance to the input and output markets, farm size, land tenure, type of farming system, and access to extension services. This study finds that after controlling for socio-economic, demographic, and regional determinants, agricultural mechanization, significantly increases the amount of cropland cultivated and is also accompanied by input intensification especially in countries where land expansion is limited. We further find significant but mixed impact of agricultural mechanization on use of household and hired labor. The mixed evidence points to a need to carry out national rather than regional assessment to better inform policy. Finally, agricultural mechanization significantly raises the productivity of maize and rice. These findings point to the importance of developing favorable arrangements that would avail mechanization to small and medium scale farmers either through animal power or tractors. This would involve providing incentives for private sector to scale agricultural mechanization initiatives and targeting and engaging both male and female farmers by investing in supportive infrastructure and farmer training at scale.

Keywords: mechanization, productivity, yield, labor, sustainable intensification, Africa

1. Introduction

Agricultural mechanization can be defined as the use of all tools, implements and machinery – from simple and basic hand tools to more sophisticated and motorized equipment (FAO, 2016). Based on the power sources, three levels of mechanization can be differentiated: human power-based mechanization, animal power-based mechanization, and mechanical power-based mechanization (Malabo Montpellier Panel, 2018). African farming systems remain the least mechanized of all continents (Pingali, 2007). Several factors have been attributed to limit mechanization and to hinder government and private sector efforts to promote mechanization among smallholder farmers in Africa. They range from market failures that limit access to machinery and spare-parts supplies, missing institutions especially those that would be required to ensure adequate technicians and skilled personnel to operate and repair farm machinery, to governance challenges such as political interest, elite capture, ineptness and corruption that constrain the government and hinder private sector's involvement in machinery importation, among others (see Daum and Birner (2017) for a recent review). Recent assessments show a positive correlation between agricultural machinery growth and agricultural output growth in Africa (Kirui and von Braun, 2018).

The biggest majority of work across African farms (50 to 85 percent) continues to be done manually through human muscle alone while about 25 and 10 percent of power for land preparation is derived from animal-powered tools and engine-powered (mainly diesel) machines respectively (FAO & ACT, 2017; Malabo Montpellier Panel, 2018). Land preparation activities such as plowing, seeding, and mowing as well as transport, pumping, and milling are key areas where animal and machine power could be used to improve agricultural productivity and diversity. Indeed animal-power-based mechanization has been found to increases the capacity of production by five to twenty times and farmers using a combination of power-based mechanization and animal power can provide enough food to feed up to 50 people compared to just six when using draught animal power alone (FAO, 2013).

Recently, there is an increasing interest by both the policy makers and the private sector to make mechanization work for the poor smallholder farmers (Mockshell and Birner, 2015; Sheahan and Barrett, 2017). Thus, several initiatives – including government importation and distribution of subsidized machinery, and private sector-lead machinery hire services– have been implemented to empower farmers to acquire or, at least, access farm machinery in different African countries such as Ghana, Mali, Benin, and Burkina Faso. So, what factors drive adoption of mechanization (at farm level) in SSA? And what is impact of mechanization on selected outcome level indicators such as total crop output, crop income, work time for agriculture, overall labor requirements and resource utilization?

The focus of the mechanization schemes have largely been on big machinery (four-wheeler tractors) and the accompanying equipment (tiller, seeders, rotavators, harvesters, driers, baler, etc.). Recent assessments of such schemes is starting to emerge in literature and they tend to focus on output indicators such as the number of imported and distributed equipment but not on the implications on end users (Bishop-Sambrook (2003); Daum & Birner (2017); Diao et al. (2014; 2016); FAO (2001; 2008); Mrema et al. (2008; 2013; 2018); Sims et al. (2016); Sims & Kienzle (2006; 2017). However, one recent study (Adu-Baffour et al., 2018) sought to find out the implications of private-sector tractor-hire services on total labor requirements and on farm income in Zambia.

The changing agricultural sector and the challenges faced by smallholders call for the need for farm mechanization suited to smallholder farming. African Agriculture is predominantly small-scale and is characterized by an abundance of natural resources, a young and growing labor force, and a rising middle class, in addition to a surge in urbanization (ACET, 2017; Jayne et al., 2018). However, smallholder farmers continue to face limited access to credit, insurance, education, technology, infrastructure, and suffer the consequences of climate change among other challenges (Barrett et al., 2017; Vanlauwe et al., 2013; Von Loeper et al., 2016).

Conventional four-wheeled tractors may not be feasible for many smallholders owing to their high capital costs, unsuitability for fragmented holdings as well as topography and slope. To complement the big imported machinery, assessment of the proliferation of the more appropriate small-scale agricultural mechanization technologies for ploughing (such manually driven two-wheeled tractors, animal-drawn or locally crafted tractor or animal drawn ploughs), weeding (such as, manual push/pull weeder, animal drawn weeder, tractor-drawn weeders), irrigation (such as solar/diesel/electric irrigation pumps) and for threshing (such as grain sheller/thresher, groundnut pod stripper) and their requisite accessories is needed.

The overall objective of this study is to assess the status and drivers of adoption, and consequently, the impact on selected outcome indicators (such as total crop output, yield, farm income, work time for agriculture, overall labor requirements and resource utilization).

This study, thus, seeks to find answers to the following research questions:

1. What is the status of agricultural mechanization at the farm level in eleven countries in Africa?
2. What are the drivers of adoption of agricultural mechanization technologies in in Africa?
3. What is the impact of animal-powered and tractor-powered agricultural mechanization on selected outcome indicators (cropland expansion, input intensification, crop productivity (yield), crop income, off-farm employment, and household and hired labor use)?

The rest of this paper is organized as follows: Section 2 surveys the literature on the important drivers and impacts of agricultural mechanization. The conceptual and empirical frameworks are outlined in section 3. Section 4 describes the data. Results and discussions are presented in Section 5. Section 6 concludes the paper with a summary of the main findings and the implications.

2. Important literature

2.1 Drivers of mechanization

The demand for mechanization in agriculture has emerged over the years due to a number of different variables. Evolution of farming systems and increase in irrigation use, access to institutional credit, increase in land size holdings, urbanization, lower risk aversion, and access to extension services and education are all drivers that have helped push mechanization's demand (Feder, 1980; Mrema, 2008; Sasmal, 2016). Although it is possible for one of the variables to have an individual influence in driving the request for such machinery, such variables typically appear in combination with one another and work together as a catalyst to drive the adoption of mechanization.

Earlier studies describe various drivers of agricultural mechanization in developing countries based on the Boserup–Ruthenberg theories of farming systems evolution. A summary of their main findings is presented in Diao et al., (2014). For example, Binswanger (1986) shows that large scale farmers are often the first-adopters of mechanization as profitability is possible for them based on preparing their own large land area. On the other hand, Pingali et al. (1987) argues that slow progress of agricultural mechanization in Africa can be explained by lack of the evolution in farming systems. As Africa rapidly urbanizes, with the number of people living in cities projected to increase from 470 million in 2015 to 770 million by 2030. Rapid urbanization, population growth, and increasing incomes all put pressure on Africa's food system to produce more varied and processed foods. (FAO, 2017). The increase in demand for such agricultural products has shifted farming systems and contributed to the expansion of farmer's lands (Diao et al, 2014). In some countries, migration from rural to larger urban areas has led to a rapid decline in farm labor supply (Goldsmith et al., 2004; Zhou, 2013; Zhang, 2015; FAO, 2018). With the rising cost of labor, farmers are more inclined to invest in machinery or to make use of machinery and technology-hiring services where they are available and affordable (Diao et al., 2017).

Evidence from a study in Ghana shows that the combination of the decrease in farm labor and increase in land has resulted in a rise in land-labor ratios and a demand for labor saving techniques, or mechanization, in agriculture (Diao et al, 2014). In northern Ghana, half of tractor owners cite land expansion as the primary motivation for investing in tractors (Chapoto et al., 2014). Another study in West Bengal, showed a positive and highly significant relationship between large sized farms and the adoption of farm mechanization (Ghosh, 2010). The increase in land also indirectly increases the demand of machinery by providing farmers greater opportunity to receive funds. By increasing a farmer's land holdings and thus their asset base, farmers have higher leverage when accessing institutional credit (ibid). The greater access to institutional credit allows these farmers to purchase or use modern machinery with less financial burden, and also creates an opportunity for farmers to generate additional revenue (Mottaleb et al, 2016). An increased number of medium-scale farmers who are also tractor owners creates new potential for hiring-out services to cater to the needs of smaller farmers, who are otherwise unable to afford investing in larger scale machinery or technologies (Chapoto et al., 2014).

One of the biggest challenges to successful mechanization across Africa is access to finance. Most farmers across the continent depend on their own savings to buy agricultural inputs, tools, and machinery. The significant upfront cost of agricultural machinery and new technologies is far beyond the reach of most smallholder farmers, who typically lack collateral for bank loans. This holds them back from investing in machinery. Collective ownership can be a solution; however, it requires time for members to accumulate adequate funding, as well as strong cooperative management and training in machinery use (Zhou, 2016). Apart from collective ownership and the access of institutional infrastructure of loan services, basic civil infrastructure such as the availability of electricity and the access to paved and graveled roads also play a significant role in the adoption and ownership of machinery (Mottaleb et al, 2016). By providing credit services and civil infrastructure, investment risk is reduced, and households are encouraged to support and adopt this new technology (Mottaleb et al, 2018).

The use of extension services and an increase education are also significant determinants of adoption of mechanization practices (Ayodele, 2012). Extension services provide access to relevant information to farmers that can help stimulate adoption of new machinery, while more years of education show a positive relationship to the actual adoption (ibid). In contrast, low literacy rates among smallholders may further hamper an efficient use of mechanical equipment (FAO, 2013). Access to education and extension services, also ties to the differences in machinery adoption for male versus female household-heads. According to a study in Bangladesh, households and farms ran by men are more likely to own, adopt or operate machinery than households headed by women (Mottaleb et al., 2018). Reasons attributed to this could come from women being less knowledgeable about effects and advantages of mechanization. This can stem from less formal education and an inability to attend extension services due to limitations of women's movements outside the household (Mottaleb et al., 2016). More formal policies that ensure gender equity in providing knowledge and access to mechanization could help further drive the use of mechanized equipment by women (Mottaleb et al., 2018).

2.2 Effects of mechanization

There are two main categories that are affected by the use of mechanization in agriculture. Farming outputs as it relates to yields, productivity levels, profitability, and crop and farm intensification, and farm labor requirements and activities, as it relates to employment and the type of tasks performed. Studies related to mechanization effecting productivity and production appear to have a similar consensus that results in a positive outcome when mechanizing, whereas studies related to effects of labor are a little more diverse in conclusions.

Among the many positive benefits of mechanization, the increase in production and productivity levels appears most frequently in studies analyzing mechanizations' effects and impact. Different studies that compare tractor to bullock farms show that the higher levels of agricultural inputs and better controls on timeliness of operations contribute to higher productivity yields for tractor farms compared to bullock farms (Verma, 2005). Access to machinery can reduce drudgery in certain farming activities and save time in land preparation (Ayodele, 2012), while an increase in the power inputs to farming activities, helps increase productivity levels on the same amount of land (FAO & UNIDO, 2008). According to one study regarding the productivity of rice farms in Ghana, the productivity of yields differs depending on the type of mechanization intensity. In this particular study, the mechanization intensity from tillage, threshing, and transportation had the most significant and positive relationship with productivity (Apiors et al, 2016). These higher levels of production and productivity levels also tie into the rise in returns-to-scale (RTS) seen in agriculture from mechanization. According to a most recent study in Ghana as it relates to maize production, mechanization is not only associated with a greater return-to-scale but the ownership of machinery, specifically tractors, causes the rise in RTS. (Takeshima et al., 2018)

Alongside the increase in production, the profitability of farms also appears to have a positive relationship with mechanization. Although equipment and machineries can be expensive, having the appropriate access to such technology at the right time can help to efficiently manage inputs in farms and overall productivity, thereby improving income (Ayodele, 2012). Higher returns seen in more mechanized farms can also be a result of lower costs in cultivation. Lower costs can be contributed to the substitution of manual labor to machinery which results in the reduction of labor requirements, as well as the overall increased efficiency of production activities (Sciences et al., 2011). This type of cost advantage seen from mechanization can be seen as necessary to stay competitive in the midst of globalization and liberalization (Ghosh, 2010).

Crop intensification and farm intensification are two other effects that have been studied as it relates to mechanization. Some studies have shown mechanized farms to have higher average cropping intensities than non-mechanized farms (Verma, 2005). On the other hand, farm intensification, more specifically fertilizer and labor intensity, appear to have a negative and significant relationship with mechanization (Houssou & Chapoto, 2015).

Agricultural mechanical technologies have contributed to global transformation of the farming landscape. These technologies have not only increase in farm size but also continue the trend toward displacing or replacing farm labor (McNulty & Grace, 2009; Boston Consulting Group, 2014). The effect of labor displacement from mechanization appears to have varying results when looked into detail. Some studies show that mechanization actually leads to a marginal increase in on-farm (household and hired) labor, and an even further increase in off-farm labor (Verma, 2005). While other studies, in developed countries, show that new technologies such as agricultural robotics will continue to displace and replace farm labor (Schmitz & Moss, 2015). Furthermore, certain studies show that although the requirement of manual labor does decrease with mechanization, it is only seen in certain stages of agricultural production, namely; land preparation, transplanting and harvesting (Chandran, 2017). Activities that require operations with more skilled labor, tend to be less affected than activities that require less skilled workers (Sciences et al, 2011).

Despite the varying studies regarding labor displacement, there is a common consensus that mechanization can benefit workers by enhancing the type of work performed. Mechanization can help facilitate better management of larger farms (Van den Berg, 2007; Boston Consulting Group, 2014) and accomplish tasks that are difficult for people to perform (FAO & UNIDO, 2008; McNulty & Grace, 2009). The reduction in drudgery and difficulty can enhance agricultural productivity (Sims & Kienzle, 2017) and overall lifestyles of farmers (FAO & UNIDO, 2008).

3. Conceptual and empirical framework

3.1 Conceptual framework

Agricultural and sectoral policies and regulations aimed at inducing changes whether in markets, pricing, infrastructure, or underlying issues such as changes in energy supply, skill development and gender and cultural norms may result in significant implications on the functioning of the economic environment for the private sector and for the farmers' objectives and constraints (Figure 1). Farmers are posited to behave rationally given a set (sets) of objectives they decided to pursue, and the constraints faced in pursuit of these objectives. For instance, a farmer who chooses to pursue income maximization may be constrained by available farmlands, capital, labor, technologies, and markets.

Many smallholder farmers are constrained by lack of capital to acquire mechanical technologies (Salami et al., 2010). Programs and initiatives may be designed to ease this constraint such as; government subsidies to aid access to agricultural machinery, machinery hire services by private sector actors or by 'better-off' and large scale farmers, or micro-credit program to improve farmer access to credit so as to hire or buy their own machinery. Furthermore, locally crafted small-scale machinery may be used instead of the conventional heavy machinery.[1]

Furthermore, farmer behavior may be expressed by; how s/he allocates productive resources (labor, land, capital) to various farm and non-farm activities, how s/he chooses to cultivate or plough his/her land (by hand-hoe, draft animals, or tractor), the quantity and quality of inputs s/he purchases, the quantity of produce s/he sells on the market, among others (Figure 1). This behavior may in turn lead to changes in the mix of crops, types and quantity of labor, seed, fertilizer, chemicals used, and the type and scale of farm power – this will not only determine the choice of crops and cropping patterns but will also determine the extent to which the farmer will perform intensification and extensification patterns. Ultimately, this behavior may result in a given output (and yield) level for a selected crop (livestock) enterprise. This would, thus, determine the farm income and household income from which the farmer derives his livelihood.

Agricultural mechanization is driven by various factors, which interact among themselves. Figure 1 is schematic representation of variables under scrutiny by the study and does not attempt to represent all the factors.

[1] Once such constraint is lifted, it is likely that farmers will adopt mechanization technologies, increase their production or productivity, and thus improve their earnings given well-functioning markets.

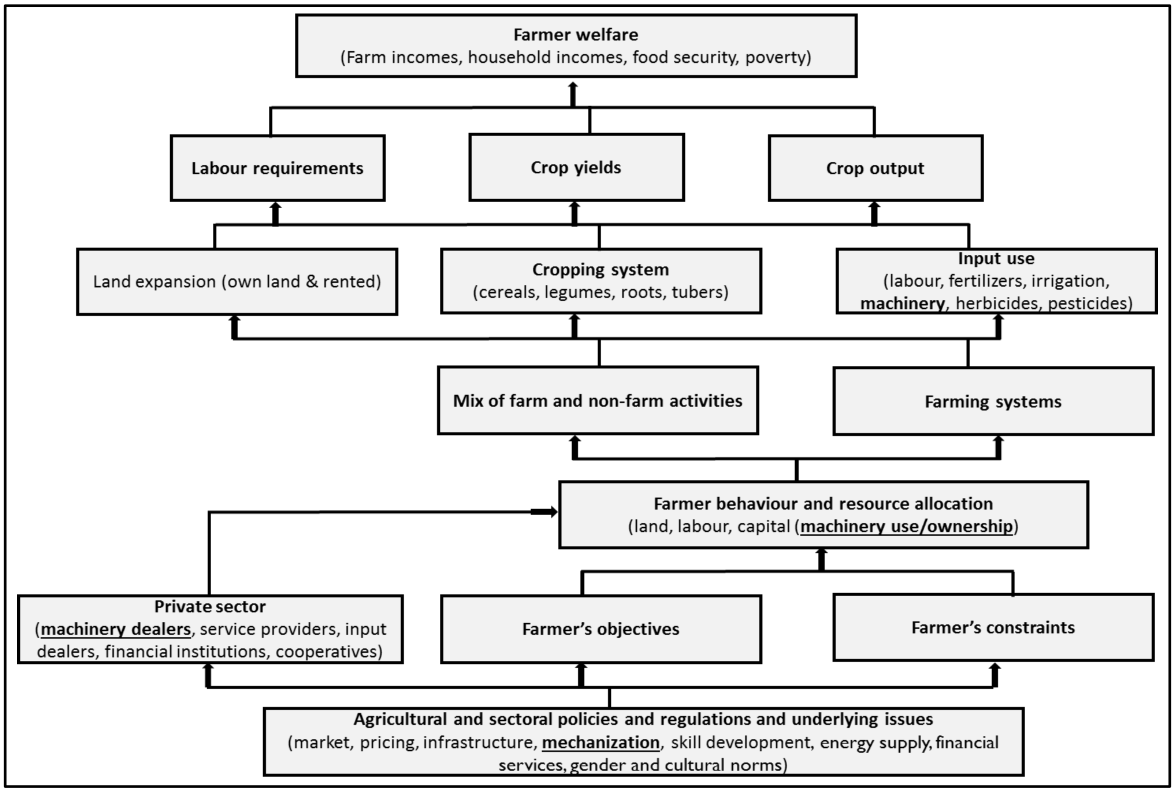

Figure 1: Conceptual framework
Source: author's creation based on review of several literature[2].

3.2 Empirical framework and estimation techniques

3.2.1 Drivers of adoption of mechanization technologies

Unlike previous studies (Ghosh, 2010 and Mottaleb et al., 2016) on drivers of mechanization that typically explore adoption of mechanization as a binomial variable – that is, whether the household or the farm plot is mechanized or not – this study allows for better insight by differentiating mechanization into three categories: those that use 1) light hand-held non-motorized machinery (no animal or tractor power used at all), 2) animal-powered machinery (can be in combination with light hand-held tools) , and 3) medium-to-heavy machinery (typically tractor-powered machinery) (this can be in combination with animal power and/or light hand-held tools).

We apply a multinomial logistic regression to estimate how marginal changes in independent variables (household, socioeconomic, and biophysical characteristics) affect the probability of being in one of three categories relative to another. The multinomial logistic model can be presented formally as follows:

$$\ln\Omega_{m|b}(x) = \ln\frac{\Pr(y=m|x)}{\Pr(y=b|x)} = x\beta_{m|b} \qquad (1)$$

for machinery choice categories m = 1 to J where b is base category (Long & Freese 2001; Hendrickx, 2002).

Our parameter of interest (β) is that marginal effect for each variable for all pairs of categories.

[2] Such as Lariviere et al. (1998); Readorn et al. (1999); Mockshell and Birner (2015); Daum and Birner (2017)

3.2.2 Impact of mechanization on cropland expansion, input intensification, use of household and hired labor, and yield of selected crops

To examine the impact of mechanization on cropland expansion, input intensification, use of household and hired labor, yield, and farm income, we estimated multinomial treatment effects models suggested by Deb and Trivedi (2006a, 2006b). Given the cross-sectional nature of the data, the alternative estimation methods which could be used include Ordinary Least Square (OLS) for continuous dependent variables or logit and probit models for (binary dependent variables). However, compared with multinomial treatment effects models, these methods may produce inefficient and biased results.

Furthermore, we need to account for the potential endogeneity of choice of the type of mechanization and the outcome variables due to self-selection (selectivity bias) and simultaneity. The choice of a particular mode of mechanization is not random because persons with higher endowments may be more likely to purchase or hire machinery. Some unobservable characteristics may affect choice of the type of mechanization and the outcomes of interest simultaneously. Failure to account for these issues may lead to biased estimates. The multinomial treatment effects model is suitable in addressing the problems of endogeneity and given the multinomial nature of the 'treatment' variable (type of mechanization).

Multinomial treatment effects model allows for the estimation of the effects of an endogenous multinomial 'treatment' variable on binary, count or continuous outcomes, while accounting for selectivity bias. Following Deb and Trivedi (2006a), we assume that farmers' choice of the type of mechanization follows a mixed multinomial distribution, and thus the probability of observing the i^{th} farmer choosing j type of mechanization can be expressed as:

$$Pr\left(v_{ij} = 1 \mid z_i, l_{ij}\right) = \frac{\exp(Z_i'\psi_j + \phi_j l_{ij})}{\sum_{k=1}^{J} \exp(Z_i'\psi_j + \phi_j l_{ij})} \quad (2)$$

where v_{ij} is the j^{th} type of mechanization ($v_{ij} = v_{i1}, v_{i2}, v_{i3}$)corresponding to light hand-held machinery, animal-drawn machinery, and tractor-powered (heavy) machinery respectively; z_i denotes exogenous covariates with respective parameters ψ_j; ψ_j contains unobservable characteristics common to the i farm household type of machinery j and outcomes, and ϕ_j are factor loading parameters associated with l_{ij}; l_{ij} are factors influence both the choice of the type of machinery and the outcome variables; μ_{ij} is an error term that is assumed to be independent and identically distributed (iid).

The outcome equation is be specified as:

$$E(y_i^*) = X_i'\beta + \delta_2 v_{i2} + \delta_3 v_{i3} + \sum_{j} \lambda_j l_{ij} + \varepsilon_i \quad (3)$$

where y_i^* is the latent variable underlying the observed outcome variables (i.e. cropland expansion, input intensification, use of household and hired labor, and yield); X_i is a set of control variables (including demographic, socioeconomic, institutional, biophysical, and regional characteristics with the associated parameters β); v_{i1}, v_{i2}, v_{i3} are dummy variables denoting animal-drawn machinery and tractor-drawn machinery relative to the base category (light hand-held machinery) respectively and δ_2, δ_3 are the respective parameters which are our main parameters of interest; l_i are the latent factors, capturing the unobserved factors that influence both the choice of the type of machinery and the outcome variables; λ are coefficients associated with unobservable characteristics and can be interpreted in terms of selection effects. For instance, $\lambda > 0$ indicates favorable selection, implying that unobserved factors that induce an individual to choose a type of machinery are associated with positive performance outcomes. Similarly, $\lambda < 0$ suggests negative selection; while $\varepsilon_i$is an iid error term.

Conditional on the common unobserved factors, the joint distribution of selection and outcome variables can be specified as:

$$\Pr\big(Y_i = y_i, v_{ij} = 1 \mid X_i, Z_i, l_{ij}\big) \; = f\left(X_i'\beta + \delta_2 v_{i2} + \delta_3 v_{i3} + \sum_{j=1}^{3} \lambda_j l_{ij}\right) X \; g\;\big(Z_i'\psi_j + \lambda_j l_{ij}\big) \qquad (4)$$

The parameters of equation (4) which is the multinomial endogenous treatment effect model are estimated using the maximum simulated likelihood procedure as proposed by Deb and Trivedi (2006) in *Stata*.

The explanatory variables (control and instruments) included in the Equation 4 ($\boldsymbol{X}$ and $\boldsymbol{Z}$) are motivated by literature on drivers and determinants of cropland expansion, agricultural intensification, farm productivity, income and profitability – as described in section two (review of relevant literature). Table 1 presents detailed description of the outcome variables, the 'treatment' variable, and the other independent variables used in the regression. Exogenous variation is exploited to improve identification by using variables in $\boldsymbol{Z}$ that influence the choice of treatment but which do not have direct effects or correlations with unobserved factors. The description of the independent variables used in the econometric analyses are also presented in Table 1. The motivation to include them is guided by the review of existing literature in chapter two and the theoretical underpinning in chapter three.

Table 1: Description of variables used in regression models

Variable	Description
Outcome variables	
Cropland area	Total area cultivated under different crops (in Ha)
Fertilizer use	Whether the household used fertilizer (1=Yes, 0=Otherwise)
Fertilizer intensity	Amount of fertilizer used in the farm (kg/ha)
Household labour	Amount of household labor used (in adult equivalent)
Hired labour use	Whether the household used hired labor (1=Yes, 0=Otherwise)
Hired labour use intensity	Number of employed persons to work in the farm
Maize yield	Amount of maize harvested per unit area (kg/ha)
Rice yield	Amount of rice harvested per unit area (kg/ha)
Independent Variables	
'Treatment variable'	
Agricultural mechanization	Type of agricultural mechanization (*1=light hand-held machinery, 2=Animal-Powered mechanization (AP mech., 3=Tractor-powered mechanization (TP mech.)*
Demographic characteristics	
age	Age of household head *(years)*
sex	sex of household head *(1=Male, 0=Otherwise)*
Edu. level	Number of years schooling of the household head
HHsize	Size of household *(adult equivalent)*
Farming characteristics	
Land tenure	Land tenure system of the main plot of the household *(1= Cultivating own-land, 2=sharecropping, 3= Communal land, 4= Rented land; 5= Borrowed land)*
Farming characteristic	*(1 = Shifting cultivation, 2 = Rotation with other crops, 3 = Continuous cropping, 4 = Mixed farming)*

Variable	Description
Socio-economic characteristics	
Market dist.	Distance from home from the market (km)
Electricity	The household has electricity (1=Yes, 0=Otherwise)
Extension	Access to extension services (1=Yes, 0=Otherwise)
Non-farm work	Engaged in off-farm (1=Yes, 0=Otherwise)
Irrigation	Whether the household uses irrigation (1=Yes, 0=Otherwise)
Extension	Whether the household accessed extension services (1=Yes, 0=Otherwise)
Farm income	Amount of farm income earned by the household (local currency)
Pesticides	Whether the household used pesticides (1=Yes, 0=Otherwise)
Livestock number	Number of livestock owned by the household (in Total Livestock Units (TLU))
Regional characteristics	
Country dummies are included in joint (pooled regressions)	

Source: author's compilation.

4. Data, sampling procedures, and description of variables

This study utilizes data from an agricultural survey for more than 9,500 African households in eleven countries: Burkina Faso, Cameroon, Ghana, Niger and Senegal in western Africa; Egypt in northern Africa; Ethiopia and Kenya in eastern Africa; South Africa, Zambia and Zimbabwe in southern Africa. This dataset was collected in 2004 and is the product of the World Bank/Global Environmental Facility project *Climate, Water and Agriculture: Impacts on and Adaptations of Agro-ecological Systems in Africa* that was coordinated by the Centre for Environmental Economics and Policy for Africa (CEEPA) at the University of Pretoria, South Africa in association with Yale University, USA and is available for public use (Waha et al., 2016)[3]

The total number of households in the data set is 9,597 following a multi-stage stratified random sampling technique. In the first stage eleven countries were selected to represent the four sub-regions of Africa East, West, North and Southern Africa. Countries from each sub-region were selected based on formal expression of interest from respective institutions within countries concerned with managing climate change impacts. In the second stage districts were selected to capture representative farms across diverse agro-climatic conditions within each country according to the FAO classification of agro-ecological zones and farming systems. Stage three sampling involved selection of villages within districts included in the survey. In each district, surveys were conducted of farms randomly selected from a list of farmers prepared with the assistance of respective district level agricultural authorities. Sampling was clustered in villages to reduce the cost of administering the survey. The number of farms selected were also proportionate to the number of farms in terms of scale of production (small-scale, medium-scale, and large-scale). The data set specifies farming systems characteristics that can help inform about the importance of each system for a country's agricultural production. This dataset is also desirable for our analysis because it is a comprehensive survey in terms of number of households interviewed and geographic coverage and provides information on mechanization in these several small scale, medium scale and large scale farms.

[3] Available online at: http://dx.doi.org/10.6084/m9.figshare.c.1574094.

Table **2** presents a summary of the multi-stage stratified sampling procedure and the corresponding number of households sampled for each country.

Table 2: number of regions, districts, subdivisions and households per country

Country	Number of administrative units level 1 (AU1)	Number of administrative units level 2 (AU2)	Number of households per AU1	Number of households
Burkina Faso	42	48	26	1,087
Cameroon	10	30	80	800
Egypt	3	20	300	900
Ethiopia	7	32	143	988
Ghana	13	61	69	894
Kenya	11	44	74	816
Niger	6	30	150	900
Senegal	9	69	120	1,078
South Africa	9	17	46	416
Zambia	9	30	112	1,008
Zimbabwe	6	24	117	700

Source: author's compilation.

Table 3 shows the distribution of the farms in terms of scale (small, medium, and large). Defining the farm size is country-specific as follows: small-scale are all farms less than 4 ha in all counties except in South Africa (less than 15 ha), medium-scale farms are farms ranging from 4 to 15 ha (15-50 ha in South Africa) and large scale farms are farm greater than 15 ha (greater than 50 ha in South Africa).

Table 3: Diversity of farms by country (percentage)

Country	Small-scale (<4 ha)	Medium-scale (4-15 ha)	Large-scale (>15 ha)
Burkina Faso	41.5	40.6	17.9
Cameroon	47.9	42.4	9.7
Egypt	67.9	15.1	17.0
Ethiopia	67.5	30.7	1.8
Ghana	84.2	11.3	4.5
Kenya	44.0	32.8	23.2
Niger	21.7	60.7	17.6
Senegal	13.0	13.3	73.7
South Africa[4]	50.1	0.0	49.9
Zambia	83.2	6.6	10.1
Zimbabwe	95.2	4.6	0.1

Source: author's compilation.

[4] In South Africa; farm sizes are categorized as follows: small-scale are farms less than 15 ha, large scale are farms greater than 50 ha.

5. Results and discussions

5.1 Status and patterns of access and ownership of mechanization

Table 4 summarizes the diversity of available machinery and the proportion of households that have access to them. In summary, the type of machinery accessed by households can be categorized into three; Light hand-held machinery, farm animal powered-machinery, and medium-to-heavy tractor –powered machinery. The data shows that, on average, light hand-held machinery is more abundant in all the countries than medium-heavy machinery and farm animal power. Overall, about 48% of the households accessed light machinery compared to 35% that accessed animal-powered machinery, and 18% that used tractor-powered machinery (Table 4).

The most common farm equipment are the hand hoe, axes, cutlasses/machetes and baskets. The countries that appear to invest most heavily in medium-heavy machinery are lager economies such as Egypt and South Africa, while Cameroon and Senegal fall on the opposite side of the spectrum. In terms of diversity and access to medium-to-heavy machinery, results show that only about 11% and 7% of the households had access to a tractor or threshers respectively. Fodder cutting machine is least popular (only 2.7 of the households had access to them. Animal drawn-plough was relatively accessible – 34% of the sampled households had access to the plough. This was varied across countries; with Egypt, Zimbabwe, and Burkina Faso having greater access (79%, 75%, and 68% respectively) while Cameroon and Ghana had the least access.

A comparison of countries' medium-to-heavy machinery access with their available farm animal power also draws an interesting connection. On average, farm animal power is relatively more available as compared to heavy machinery in most countries. Although Burkina Faso appears to have the highest use of bullocks and Zimbabwe the highest use of Mules, they also have some of the lowest proportion of those households with access to tractors. While South Africa which has the highest proportion of household owning tractors, it appears to have one of the lowest implementations of farm animal power.

In summary, the type of machinery accessed by households can be categorized into three; Light hand-held machinery, farm animal powered-machinery, and medium-to-heavy tractor –powered machinery. Overall, about 48% of the households accessed light machinery compared to 35% that accessed animal-powered machinery, and 18% that used tractor-powered machinery (Table 4). The variation for each of the category is evident in each country. For example, light hand-held machinery is predominant in Cameroon (97%), Ghana (82%) and Zambia (81%) while animal-powered machinery is the main type of mechanization in Senegal (79%), Burkina Faso (69%) and Zimbabwe (65%). Tractor-powered machinery, as expected, is largely common in more developed counties like Egypt (90%) and South Africa (72%). Kenya comes a distant third – with 21% of farm households using tractor-powered machinery. We further present the average number of these equipment owned/access by the household in the Appendix Table A1 in which it further corroborates the very low number of medium-to-heavy tools/ equipment/ machinery owned or accessed per household.

Table 4: Access to machinery, tools, and implements (proportion of households)

	Access to Machinery, Tools, and Implements (% of households)											
	Burkina Faso	Cameroon	Egypt	Ethiopia	Ghana	Kenya	Niger	Senegal	South Africa	Zambia	Zimbabwe	Total
Light Machinery												
Cutlass/ machete	91.8	99.4	26.1	55.4	99.6	92.2	82.9	91.3	20.2	25.0	19.1	67.1
Hoe	99.1	93.3	35.6	83.4	88.6	97.5	85.2	82.0	48.0	95.1	99.3	84.2
File	39.1	88.3	6.5	18.8	5.6	83.4	16.1	13.7	13.6	13.6	27.1	29.1
Axe	93.1	59.6	91.3	84.6	26.0	89.6	84.2	73.5	24.5	90.2	84.4	75.7
Baskets	65.3	84.3	24.9	53.1	72.6	62.5	40.4	26.3	18.5	32.6	27.2	47.4
Weeder	33.7	23.3	17.9	25.1	2.0	11.0	47.3	65.8	13.1	5.7	3.6	24.4
Others	22.2	28.1	27.2	24.9	8.2	40.0	40.2	44.7	21.3	12.9	37.2	28.0
Average	*26.1*	*96.7*	*5.2*	*38.3*	*82.0*	*61.3*	*49.7*	*20.8*	*23.7*	*81.4*	*33.4*	*47.9*
Medium-heavy Machinery												
Tractor	0.9	0.0	56.8	4.5	11.9	12.8	0.3	0.0	69.2	6.9	1.4	11.7
Plough	67.6	0.0	79.2	21.7	9.3	26.3	18.4	28.7	51.0	16.8	74.8	34.3
Trolley/Trailer	51.8	0.0	5.2	0.3	1.7	14.4	8.1	14.1	42.0	7.9	1.6	12.5
Thresher	2.1	0.0	62.7	0.1	0.8	4.0	0.3	0.0	19.3	1.6	0.1	7.4
Fodder cutting machine	1.2	0.0	7.4	1.3	0.4	10.5	0.0	0.0	18.5	0.8	0.0	2.7
Generator/diesel pump	2.2	2.8	65.5	0.4	1.2	10.0	7.1	0.1	24.8	2.4	0.0	9.5
Spraying machines[5]	21.9	19.6	4.5	2.6	11.9	36.1	12.6	0.0	34.1	8.1	0.7	12.4
Others	9.8	4.4	4.3	0.1	1.3	19.7	16.0	25.6	19.3	3.9	41.4	12.4
Average	*5.0*	*2.8*	*90.8*	*6.2*	*12.7*	*21.3*	*7.8*	*0.1*	*71.9*	*8.5*	*1.4*	*17.5*
Farm animal power												
Bullocks	51.1	0.5	12.1	41.9	6.8	17.9	33.1	17.8	5.2	11.0	9.0	20.4
Mules	57.9	0.1	9.9	10.2	0.6	2.5	25.9	34.6	2.2	1.6	65.1	20.0
Others	0.3	0.0	22.7	21.1	0.1	5.0	10.4	59.1	0.8	2.2	10.0	13.5
Average	*68.8*	*0.5*	*4.0*	*55.5*	*5.3*	*17.4*	*42.5*	*79.1*	*4.4*	*9.8*	*65.1*	*34.6*

Source: author's compilation.

[5] For applying chemicals and/or fertilizers. Note; some of the medium-heavy equipment (such as threshers and ploughs) are either tractor powered or stand-alone too.

It is also vital to assess the actual mode of ownership of the said machinery and tools. We present the proportion of households without actual access (and thus no ownership of each of the machinery and tools), households who owned, households who jointly owned with other households, and households who have leased or hired the equipment for own use or for joint use with other households Table 5. The majority of households do not have access or ownership to most of these tools, especially medium-heavy machinery. For medium-heavy machinery, in particular tractors, ploughs and threshers, there is a higher proportion of households that hire for rent the medium-heavy machinery rather than jointly owning with other households. The least likely type of machinery for households to own are fodder cutting machines, threshers and generator diesel pumps while the most likely tools to own are axes, hoes, and cutlasses/machetes. The proportion of the households that own cutlass, hoe, file, axe, baskets and weeders is at 66%, 82%, 29%, 74%, 45% and 24% respectively. Joint ownership of these equipment/tools is very low (less than 1%). Slightly more households hire tractors (7%), plough (8%), threshers (6%) and diesel powered generators.

Table 5: Ownership of machinery, tools, and implements (proportion of households)

	Household without access or ownership	Owned by household (A)	Jointly owned with other households (B)	Hired for household or joint use (C)	Combina tion of A,B,C
Light Machinery					
Cutlass/machete	32.9	66.0	0.7	0.2	0.1
Hoe	16.0	82.3	1.4	0.3	0.1
File	71.0	28.5	0.4	0.0	0.0
Axe	24.5	74.3	1.1	0.1	0.0
Baskets	53.0	45.7	1.2	0.2	0.0
Weeders	75.6	23.9	0.4	0.1	0.0
Medium-heavy Machinery					
Tractor	88.4	4.2	0.4	6.9	0.1
Plough[6]	65.8	25.0	1.3	7.9	0.0
Trolley/Trailer	87.6	11.4	0.2	0.7	0.0
Thresher	92.6	1.8	0.1	5.5	0.0
Fodder cutting machine	97.3	2.0	0.1	0.6	0.0
Generator/diesel pumps	90.5	5.4	0.4	3.7	0.0
Spraying machines	87.6	10.7	0.6	1.1	0.0
Farm animal power					
Bullocks	79.7	19.2	0.6	0.5	0.0
Mules	80.2	19.3	0.3	0.2	0.0

Source: author's compilation.

We also assess the use of different machinery on average and by scale of farm operations. Results (
Table **6**) show that light machinery is predominantly used in small and medium scale farms. For instance, cutclass, hoe and axe are used by about 67%, 86% and 75% of small-scale farmers, about 81%, 87%, and 82% of medium scale farmers and only 21%,46%, and 11% of large-scale farmers. Similarly, as expected, the use of tractors and associated implements is much higher in medium and large scale farms. For example, about 78% of the large scale farmers use tractors and ploughs and about 72% use threshers. Farm animal power is predominantly used by medium scale farmers. The proportion of these farmers using bullocks and mules (30% and 22% respectively) is higher the other types of farmers.

[6] Oxen or mule-drawn plough

Table 6: Machinery use by farm size

	Small-scale (<4 ha)	Medium-scale (4-15 ha)	Large-scale (>15 ha)	Total
Light Machinery				
Cutlass/ machete	57.0	80.8	21.4	67.1
Hoe	85.5	86.7	45.6	84.2
File	24.9	37.5	28.4	29.1
Axe	74.6	81.6	10.9	75.7
Baskets	46.6	57.4	7.4	47.4
Weeder	15.2	29.4	13.8	24.4
Medium-heavy Machinery				
Tractor	10.1	7.3	78.0	11.7
Plough	31.1	32.3	77.8	34.3
Trolley/Trailer	5.6	14.8	30.3	12.5
Thresher	7.1	5.4	71.7	7.4
Fodder cutting machine	1.3	2.1	37.2	2.7
Generator /diesel pump	9.0	7.2	43.7	9.5
Spraying machines	7.9	16.9	19.5	12.4
Farm animal power				
Bullocks	15.3	30.1	22.2	20.4
Mules	16.3	22.8	26.4	20.0

Source: author's compilation.

5.2 Drivers of agricultural mechanization

The results of the multinomial logit models to assess the drivers of agricultural mechanization are presented in Table 7 and Table 8. They present the determinants of the use of animal-powered mechanization and medium-to-heavy mechanization (which involves use of tractor-drawn equipment) with the comparison category set as the users of hand held tools respectively. We estimate the results for a pooled sample (joint model) and for each individual country. Findings suggest the significance of several demographic, socio-economic, institutional, and regional variables in determining the use of animal-powered and tractor-powered mechanization, albeit these results are mixed across countries.

5.2.1 Animal-powered mechanization

In the assessment of determinants of animal-powered mechanization for land preparation results (Table 7) of the joint model show that male-headed households are significantly more likely to adopt this method as compared to users of hand held rudimentary tools. Male headed households are 63% more likely to use animal-powered mechanization while an additional household member (adult equivalent) increase the probability of using animal-powered mechanization by about 10%, *ceteris paribus*. Earlier studies found that women were less knowledgeable about effects and advantages of mechanization as a result of such factors as less formal education, an inability to attend extension services, and limitations of women's movements outside the household (Mottaleb et al., 2016). This study attempts to control for these variables, thus, this finding may essentially point to discrimination against women.

Findings further show that larger households in Burkina Faso, Ethiopia, Ghana, Kenya, Senegal and Zimbabwe tend to adopt animal-powered mechanization. The probability of using animal-powered mechanization increases with the size of the household by about 7% in Burkina Faso, Ethiopia and Ghana, by 16% in Kenya, 11% in Senegal and 10% in Zimbabwe, *ceteris paribus*. The increasing number of household members may imply an increase in demand for food and other agricultural products necessitating an increase in mechanized operations. Earlier findings (Diao et al, 2014) suggests that increasing population has led to a shift in farming systems and contributed to the expansion of farmer's lands through mechanized operations.

Education level of the household head does play a critical role in enhancing the adoption of animal-powered mechanization in Senegal and Zambia; it increases probability of using animal-powered mechanization by about 5% and 11% respectively, *ceteris paribus*. Following earlier findings by Ayodele (2012) and FAO (2013), we contend that increasing the level of education and literacy is a potent approach to provide knowledge about the different machines and equipment and to increase the efficiency of using such machinery and equipment. Low literacy rates among smallholders is believed to be one of the main deterrent to use of mechanized equipment in SSA (FAO, 2013). Education level of the household head seems to be an extraneous driver of mechanization. This implies that the average level of education of animal-powered mechanization and that of light-hand held tools is relatively the same. Households whose heads engage in nonfarm activities to generate income are more likely to use animal-powered mechanization by about 15% in the pooled sample, 57% in Ethiopia but 53% less likely in Niger *ceteris paribus.*

Results further suggest that distance to the market is a significant determinant in aiding use of animal-powered mechanization in the joint model, and in both Niger and Senegal. Though the magnitude of the coefficient is low (about 1%), households located further away from the markets are more likely to use animal-powered mechanization in all these three cases, while holding other factors constant. The probability of using animal-powered mechanization increases with the increase in size of the farm by about 1% in the joint model, 40% in Ghana, and 28% in Senegal, *ceteris paribus*. Larger farms and availability of land for cropland expansion have been found to motivate the use as well as the acquisition of farm machinery (Chapoto et al., 2014; Ghosh, 2010). The abundant availability of arable land is deemed to indirectly increase the demand of machinery.

Furthermore, households with access to electricity are less likely to use animal-powered mechanization in Kenya and Senegal but more likely in Niger and Zimbabwe. The positive and significant effects of electricity on animal-powered mechanization corroborate earlier findings that basic civil infrastructure such as availability of electricity and the access to roads reduces investment risks and thus play a significant role in the adoption and ownership of machinery (Mottaleb et al, 2016). However, negative significant effects might imply that households are wealthier and could afford to use the more expensive tractor-powered equipment.

The land tenure system is also an important driver of animal-powered mechanization. With share-cropping as the comparison category, results of the joint model shows that animal-powered mechanization is 26% and 83% more likely in own-land and rented land, but 69% less likely on borrowed land *ceteris paribus*. The probability of using animal-powered mechanization is 48%, 86%, 35%, 9% and 47% more in rented farm land in Burkina Faso, Ethiopia, Kenya, South Africa and Zambia (as compared to sharecropping). However, the probability of using animal-powered mechanization is 83% and 11% less likely in borrowed farm land in Ethiopia and Kenya, *ceteris paribus.* This might imply that insecure tenure associated with borrowed farmland discourages investment in mechanized operations.

Table 7: Drivers of agricultural mechanization: animal drawn-machinery

	Pooled	Burkina Faso	Cameroon	Egypt	Ethiopia	Ghana	Kenya	Niger	Senegal	South Africa	Zambia	Zimbabwe
Age	0.00	0.00	0.99	0.03	-0.015*	0.01	0.026*	0.00	0.00	-0.107	0.00	0.01
Male	0.632***	1.21	-7.59	-0.16	0.44	0.98	0.41	0.28	1.413***	1.79	0.29	0.12
Edu. level	0.00	0.05	2.23	-0.01	0.02	-0.03	0.02	0.00	0.048*	0.196	0.105***	0.00
HH size	0.100***	0.073***	1.19	0.29***	0.067*	0.063*	0.162***	0.02	0.107***	-0.01	0.07	0.103*
Electricity	-0.12	14.77	6.69	0.00	0.24	-0.22	-2.229***	0.611**	-0.546*	-1.677**	-0.80	1.582**
Non-farm work	0.152**	0.13	-4.71	-0.79	0.568***	0.15	0.16	-0.532***	0.17	-0.28	-0.06	0.241
land size	0.003*	-0.03	0.52	0.16	0.212	0.401**	0.00	0.01	0.280***	0.585	0.01	0.04
Market dist.	0.006***	0.00	0.56	0.00	-0.01	-0.01	0.00	0.011***	0.01	0.01	0.00	0.00
Land tenure												
Own-land	0.26**	0.03	0.00	1.43	0.378*	0.00	0.122**	0.00	0.00	-0.11	0.189**	0.00
Communal land	0.53	-0.27	-30.61	-10.48	0.25	1.35***	0.232	-0.62	-0.17	-0.85	-0.095**	0.10
Rented land	0.829*	0.48**	0.05	1.43	0.863***	0.18	0.35***	-0.64	-0.59	0.09**	0.476**	14.81
Borrowed land	-0.69**	0.46	1.37	1.21	-0.83**	-0.67	-0.11**	-1.03	0.36	-0.96	0.132**	-1.60
Farming system												
Shifting cultivation	0.453***	-0.81	0.00	-0.79	0.450*	0.50**	-0.86	0.00	0.00	0.90	0.49**	0.00
Rotation with crops	-0.406**	-0.35	-0.50	-0.358*	-0.928**	0.78	-0.46	0.857**	0.197***	0.56	0.57	-0.37
Mixed farming	0.494**	-0.18	0.81	0.00	0.50	-0.01	0.644*	0.26**	0.90	0.03	0.73	0.06
Irrigation	-0.66***	0.15	-6.52	-0.51	-0.96**	0.73***	-0.810**	-0.918***	-0.713***	-0.92	0.47	-0.520**
Extension	0.535***	0.63**	6.87	-0.71	0.08	0.49	0.622**	0.04	0.362***	0.423***	0.640*	0.95***
Farm income	0.00	0.00	0.00	0.00	0.000**	0.000**	0.00	0.000*	0.359***	0.00	0.227*	0.00
HH Labour	0.001***	0.00	0.01	-0.01	0.001***	0.00	0.001*	0.001***	0.003***	-0.33	0.00	0.001**
Hired labor	0.00	0.00	0.10	0.00	0.00	0.00	0.00	0.00	-0.060***	0.21	0.00	0.00
Fertilizer	0.257***	-0.86	-0.85	0.53	0.786***	-15.99	0.02	0.26	-0.02	-16.89	0.00	0.00
Pesticides	0.318***	0.760**	0.69	-0.55	0.396*	-1.638**	0.24	0.785***	-0.25	0.86	0.71***	-0.09
Livestock number	0.000**	0.00	0.00	0.210	0.00	0.008**	0.00	0.01	0.008*	0.00	0.00	0.06***
Country dummies												
Cameroon	-0.408***											
Egypt	-0.581**											
Ethiopia	-0.315**											
Ghana	-0.647***											
Kenya	-0.485***											
Niger	-0.859***											

Senegal	0.907***											
South Africa	-0.548***											
Zambia	-0.361***											
Zimbabwe	0.840***											
Constant	-0.72	-1.17	-166.74	-15.25	1.21	-19.15	-4.445***	-3.630***	-2.110**	2.63	-21.99	-1.472*
N	9322	995	795	865	951	891	806	896	1068	367	997	691
Chi^2	8503.2	271.62	114.84	186.59	416.95	278.96	296.02	446.53	401.62	200.28	452.70	238.19
R^2	0.45	0.18	0.46	0.29	0.25	0.27	0.20	0.27	0.36	0.38	0.38	0.24
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: author’s compilation.

With regards to farming system results show that, compared to continuous mono-cropping (reference category), shifting cultivation increases the probability of using animal-powered mechanization by about 45% in the joint model, 45% in Ethiopia, 50% in Ghana, and 49% in Zambia. Rotational cropping system (compared to mono-cropping) however showed mixed results: reduces probability of using animal-powered mechanization by about 41% in the overall model, 36% in Egypt, 28% in Ethiopia; but increases the probability of using animal-powered mechanization by about 86% in Niger and 20% in Senegal. Moreover, mixed farming increases the probability of using animal-powered mechanization by about 49% in the joint model, 26% in Niger and about 64% in Kenya, and 13% in Zambia.

Irrigation reduces the probability of using animal-powered mechanization by about 66% in the joint model, 96% in Ethiopia, 81% in Kenya, 92% in Niger, 71% in Senegal, and 52% in Zimbabwe, *ceteris paribus*. However, irrigation increases probability of using animal-powered mechanization only in Ghana (by about 93%) *ceteris* paribus. The findings on irrigation may signify increased probability to use tractors. Overall, access to extension services significantly increases the probability of using animal-powered mechanization by about 54% in the joint model. At country level, access to extension services enhances the use of animal-powered mechanization in Burkina Faso (63%), Kenya (62%), Senegal (36%), South Africa (42%), Zambia (64%), and in Zimbabwe (95%). Farm income increases the probability of using animal-powered mechanization in Ethiopia, Ghana, Niger, Senegal and Zambia. Similar to education, extension services would increase knowledge about available machinery and efficient use of the machinery (FAO (2013) & Zhou (2016)).

The number of household and hired laborers have mixed effects on the probability of using animal-powered mechanization. On the one hand, the number of household laborers increases the probability of using animal-powered mechanization in the overall model, Ethiopia, Kenya, and Niger but reduces the probability of using animal-powered mechanization in Senegal and Zimbabwe. On the other hand, the number of hired laborers increases the probability of using animal-powered mechanization in the Kenya but reduces the probability of using animal-powered mechanization in Senegal.

The use of fertilizer and the use of pesticides have significant effects on the probability of using animal-powered mechanization – they increase the probability of using animal-powered mechanization by about 26% and 32% respectively. Fertilizer use increases the probability of using animal-powered mechanization by about 85% in Cameroon and 79% in Ethiopia. Similarly, use of pesticides increases the probability of using animal-powered mechanization by about 76%in Burkina Faso, 40% in Ethiopia, 79% in Niger, and 31% in Zambia, *ceteris paribus*. As a production package, farmers who can purchase production inputs might be able to accompany that with the use of animal or tractor drawn machinery (which would typically involve hiring the services from medium and large scale farmers (Chapoto et al., 2014; Mottaleb et al, 2016)).

Ownership of livestock have a positive significant effect on the probability using animal-powered mechanization in all cases – joint model, Ghana, Senegal, and Zimbabwe. Similarly, the use of animal-powered mechanization is significantly higher in Senegal and Zimbabwe by about 90% and 84% respectively compared to the base category (Burkina Faso), holding other factors constant. These animals would also play different roles for the farmers – source of manure, source of meat and source of cash when sold out.

Overall, the use of animal-powered mechanization is significantly lower in all the other countries as compared to Burkina Faso (base country) – by about 41% in Cameroon, 58% in Egypt, 65% in Ghana, 49% in Kenya, 86% in Niger, 55% in South Africa and 36% in Zambia, *ceteris paribus*.

5.2.2 Tractor-powered mechanization

In the assessment of determinants of tractor-powered mechanization, results (Table 8) show that age of the household head significantly influences use of tractor power in land preparation. The use of tractors increases with age in the pooled sample, Kenya, Niger, Zambia, and Zimbabwe. However, use of tractors tend to reduce with increase in age of the household head in Burkina Faso and Egypt. Furthermore, male-headed households in Niger are 26% more likely to use this method as compared to users of hand held rudimentary tools. As noted earlier, this might be attributed to the fact that women are less knowledgeable about effects and advantages of mechanization because they have less formal education, inability to attend extension services, and their limited movements outside the household (Mottaleb et al., 2016).

The education level of the household head is significant in explaining the use of tractor-powered mechanization. It increases, *ceteris paribus*, the probability of using tractor-powered mechanization by about 7%, 11%, 8%, 14%, 12% and 26% in the joint model, Cameroon, Ethiopia, Kenya, South Africa, and Zambia, respectively. Education increases knowledge about the different machines, equipment and tools and also increase the efficiency of using such machinery and equipment (Ayodele (2012) and FAO, (2013)).

Results further show that the larger the household size, the higher the probability of using tractor-powered mechanization in all the cases (joint model, Burkina Faso, Ghana, Kenya, and Zambia). Similar findings are reported by Diao et al. (2014) who suggests that increasing population has led to a shift in farming systems and contributed to the expansion of farmer's land through mechanized operations. Households whose heads engage in nonfarm activities to generate income are more likely to use tractor-powered mechanization by about 74% and 65% in Ghana and South Africa but 16%, 26%, and 83% less likely to use tractor-powered mechanization in the pooled sample, Cameroon, and Ethiopia, , *ceteris paribus*. Similar to animal-powered mechanization, we argue that mechanization could cause a shift towards off-farm work – which would induce labor-capital substitution due to the rise in land-labor ratio. This, consequently, would lead to rising labor cost and thus demand for labor saving techniques, or mechanization (Diao et al, 2014; 2017). However, in Cameroon, Ethiopia and the joint model show negative significant relationship between non-farm work and use of medium-to-heavy machinery. This might be explained by the fact that though farm machinery are able to substitute animal power and/or human labor, they would not replace the human labor completely. Most machinery are used for land preparations and it cannot cover the highest labor intensive farm activities such as weeding, transplanting, threshing, and harvesting. Household heads working off-farm might require to hire more labor for such intensive activities.

Farm size significantly increases the probability of using tractor-powered mechanization in Egypt, Niger, Zambia and Zimbabwe. This corroborates earlier findings that larger farms and availability of land for cropland expansion have been found to motivate the use as well as the acquisition of farm machinery (Chapoto et al., 2014; Ghosh, 2010). The land tenure system is also an important driver of tractor-powered mechanization. With share-cropping as the comparison category, results of the joint model shows that tractor-powered mechanization is 33% more likely in rented land, but 8% less likely on borrowed land *ceteris paribus*.

The probability of using tractor-powered mechanization is 14%, and 51% more in rented farm land in Ghana and Kenya respectively (as compared to sharecropping). However, the probability of using tractor-powered mechanization is 27% and 11% less likely in borrowed farms land in Ethiopia and Niger respectively, *ceteris paribus*.

Table 8: Drivers of agricultural mechanization: medium-to-heavy machinery

	Pooled	Burkina Faso	Cameroon	Egypt	Ethiopia	Ghana	Kenya	Niger	Senegal	South Africa	Zambia	Zimbabwe
Age	0.016***	-0.031*	0.01	-0.031*	-0.02	0.01	0.049***	0.029*	-0.26	-0.01	0.039***	0.108*
Male	0.14	0.08	1.98	-0.25	14.61	0.82	-0.34	-2.262**	2.25	0.53	-0.47	-17.15
Edu. level	0.073***	0.12	0.115**	0.02	0.077*	0.059	0.144***	0.04	0.51	0.12***	0.263***	0.00
HH size	0.103***	0.11***	-0.07	0.02	0.01	0.075***	0.136***	-0.06	-0.32	-0.07	0.262***	1.150***
Electricity	1.002***	14.90	-0.39	0.00	0.22	0.12	0.587**	1.486***	8.21	-0.09	1.164**	5.533***
Non-farm work	-0.161*	-0.29	-0.26**	-0.21	-0.831*	0.741***	0.01	0.68	-2.49	0.650*	-0.64	
Land size	0.00	0.01	-0.20	0.28**		-0.03	0.00	0.047*	0.55		0.023***	0.520***
Market dist.	0.005***	-0.01	0.01	-0.01	0.00	-0.041***	0.010**	-0.018***	0.00	0.01	0.00	0.00
Land tenure												
Own-land	0.01	0.52	0.00	-30.62	12.50	0.00	0.23	0.00	0.00	-19.12	0.89	0.00
Communal land	-0.22	0.95	-17.81	-44.44	-2.81	0.404	0.44	-14.89	-0.98	-18.67	-21.58	-1.33
Rented land	0.33***	0.79	-0.55	-29.97	14.90	0.142***	0.51**	0.83	3.72	-18.97	-16.14	-9.52
Borrowed land	-0.082*	0.01	-1.01	-30.05	-0.27**	0.50	0.28	-11.82	0.12	-21.37	-0.01	-13.36
Farming system												
Shifting cult.	-0.12	0.86	0.00	-0.48	0.43	0.13	-0.51	0.00	0.00	0.77	-0.08	0.00
Rotation with crops	0.50	0.63	-0.02	-0.05	0.54	0.40	-0.21	0.401***	0.11	0.44	-0.48	-0.49
Mixed farming	0.10	-0.08	-0.85	0.00	0.56	0.26	0.07	0.17	0.15	-0.47	0.19	-0.99
Irrigation	0.343***	0.45***	0.269***	-0.99	0.263***	0.486***	0.10	0.810***	-1.91	-0.60	0.391*	-0.251**
Extension	0.393***	-0.39	0.24	-0.60	-0.64	0.939***	0.792***	0.401**	0.27	0.132**	-0.13	0.15
Farm income	0.000*	0.00	0.00	0.00	0.00	0.00	0.000**	0.000**	-2.07	0.000*	0.360**	0.00
Nonfarm income	0.00	0.00***		0.00	0.00	0.00	0.00	-0.000*	-2.19	0.00	-0.15	0.00
HH Labour	0.001***	0.00	0.00	0.00	0.001***	0.00	0.00	0.00	0.01	0.00	-0.01	0.00
Hired labor	0.00	0.00	-0.78	0.00	0.00	0.002***	0.00	0.003***	-0.94	0.39	0.00	0.01
Fertilizer	0.283*	-0.05	0.62	0.21	-0.58	-0.35	-0.01	0.975***	-7.87	1.38		
Pesticides	0.670***	0.99***	-0.37	0.26	-0.79	0.41	0.065***	0.354***	5.29	0.40	0.101*	0.03
Livestock number	0.000**	0.00	0.001***		0.01	0.00	0.00	0.01	0.01	0.003**	0.00	0.073**
Country dummies												
Cameroon	-0.290***											
Egypt	0.041***											
Ethiopia	-0.481*											
Ghana	-0.346***											
Kenya	-0.42											

Niger	-0.378***											
Senegal	-0.571***											
South Africa	0.513***											
Zambia	-0.676***											
Zimbabwe	-0.187***											
Constant	-0.569***	-13.28	-23.75	21.02	-33.21	-21.67	-6.328***	-8.256***	0.53	18.96	-6.315***	-17.203***
N	9322	995	795	865	951	891	806	896	1068	367	997	691
Chi^2	8503.24	271.62	114.84	186.59	416.95	278.96	296.02	446.53	401.62	200.28	452.70	238.19
R^2	0.45	0.18	0.46	0.29	0.25	0.27	0.20	0.27	0.36	0.38	0.38	0.24
p-value	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Source: author’s compilation.

5.3 Impact of agricultural mechanization on selected outcomes

We discuss the results of the of the second stage (outcome equation) of the multinomial treatment effects models applied in this study – which estimates the effects of the type of mechanization used on the selected outcome variables. We estimate the effects of Animal-Powered (AM) mechanization and Tractor-Powered (TP) mechanization relative to use of light hand-held machinery on cropland expansion, input intensification, use and intensity of use of household and hired labor as well as on productivity of selected crops. For prudence, and due to complexity of describing each of the results for the several outcome variables and the multiple equations estimated for each country, we only focus on the most relevant coefficients (i.e. results of the 'treatment' variable) as presented in Table 9. We prefer to report marginal effects instead of the coefficients for simplicity and for proper inference. Full estimation results for each of the eleven countries and the joint model are reported in Tables A2 – A9 in the Appendix. The tables in the appendix also shows that some of the sample selection bias correction terms (λ) are either negative or positive but all statistically significant coefficients – implying that without controlling for selection bias the estimated impact of education would have been downwardly biased or upwardly biased respectively.

The results show that after controlling for socio-economic, demographic, and regional determinants, agricultural mechanization (animal-powered and tractor-powered), as compared to those using of light hand-held machinery, significantly increases the amount of cropland cultivated in the joint model by about 7 ha for animal-powered mechanization and about 51 ha for the tractor-powered mechanization. Animal-powered mechanization increases the amount of cropland cultivated by 3 ha in Burkina Faso, 1.6 ha in Ethiopia and 2.3 ha in Zimbabwe. On the other hand, tractor-powered mechanization increases the amount of cropland by 14 ha in Egypt, 3 ha in Ethiopia, 0.2 ha in Kenya, 0.7 ha in Senegal, 46 ha in South Africa, 0.6 ha in Zambia, and 3 4 ha in Zimbabwe, *ceteris paribus*. Earlier studies have shown that availability of land for cropland expansion increases the use and the acquisition of farm machinery (Ghosh, 2010; Chapoto et al., 2014; Daum & Birner, 2017; Adu-Baffour et al., 2018). In other words, the demand for machinery increases with the availability of arable land.

Results further show that animal-powered and tractor-powered mechanization increases with the use and intensity of use of fertilizer. As a production package, farmers could simultaneously use production inputs and mechanize their operations (Chapoto et al., 2014; Mottaleb et al, 2016). Results show a significant increase in the use of fertilizers in Burkina Faso, Ghana, Niger, and Senegal together with animal-powered mechanization. Similarly, tractor-powered mechanization is accompanied with increased use of fertilizer by in Burkina Faso, Ethiopia, Ghana, Kenya, Niger and Senegal.

Findings further suggest that both animal-powered and tractor-powered mechanization have significant effect on the use of household and hired labor. While animal-powered mechanization increases the amount of household labor by 2, 3, 3and 5 adult equivalents in the joint model, Ethiopia, Niger, and Zambia respectively, it reduces the amount of household labor by 5 and 4 adult equivalents in Senegal and Zimbabwe respectively, *ceteris paribus*. Tractor-powered mechanization increase the amount of household labor only in Cameroon (by 3 adult equivalents) but reduces the amount of household labor by 1.6, 4, and 1.7 adult equivalents in the joint model, Ghana, and South Africa, *ceteris paribus*.

The use of animal-powered mechanization increases the probability of using hired labor by about 20%, 21%, and 4% I the joint model, Cameroon, and Senegal but reduces the probability of using hired labor by about 10% in Ethiopia. Tractor-powered mechanization on the other hand increases the probability of using hired labor by about 16%, 22%, 12%, 21% and 37% in the joint model, Ghana, Niger, Zambia and Zimbabwe but reduces the probability of using hired labor by about 23% in Ethiopia.

Table 9: Impact of mechanization on selected outcomes (summary table)

	Level of mech.	Pooled	Burkina Faso	Cameroon	Egypt	Ethiopia	Ghana	Kenya	Niger	Senegal	South Africa	Zambia	Zimbabwe
Cropland Expansion	AP mech.	5.6**	3.11**	-0.19	0.36	1.6**	-0.85	6.86	-1.30	0.37	39.6	1.57	2.32**
	TP mech.	15.7***	5.32	-0.36	13.93**	43.4*	-0.27	0.21**	8.19	0.70*	46.2**	9.6***	3.8***
Fertilizer use (dummy)	AP mech.	0.26***	0.07**	0.01	0.03	-0.10	0.16***	-0.041	0.07**	0.09**	-0.05	-0.02	-0.01
	TP mech.	0.40***	0.12*	0.05	0.02	0.19***	0.27***	0.12***	0.18***	0.95**	0.05	0.09	0.09
Fertilizer use intensity ($kgha^{-1}$)	AP mech.	1.25	-2.58	18.7**	-21.24	-4.2**	-0.35	-16.53	0.51	7.9***	240.9	-11.93	56.69
	TP mech.	13.2**	-17.03	10.9***	45.07	8.1**	66.9***	34.52***	7.5***	-36.02	137.1**	36.64	58.87
Amount of HH labor (#)	AP mech.	2.3**	-8.2	-1.8	-7.9	2.5*	6.6	0.8	2.6**	-4.7***	-1.7	5.1***	-3.9***
	TP mech.	-1.60*	6.1	2.6***	-2.9	28.4	-4.0*	2.6	6.0	-7.3	-1.7**	-5.6	-11.9
Hired labor use (dummy)	AP mech.	0.20**	-0.02	0.21***	-0.08	-0.10***	0.11	0.00	0.00	0.04***	0.0	0.01	-0.06
	TP mech.	0.16***	0.02	-0.02	0.04	-0.23***	0.22***	0.02	0.12*	-0.17	0.0	0.21***	0.37**
Intensity of hired labor (#)	AP mech.	0.96	-49.54	2.56	-3.74*	-3.83**	3.48	-8.9	-4.44*	2.5***	-2.9*	-9.16	5.19
	TP mech.	5.4***	-8.14	-1.51	-73.11	-4.05***	2.1***	-13.3**	2.21***	-8.02**	0.63	2.82	3.1***
Maize yield kg/ha)		(n=4652)	(n=500)	(n=431)	(n=263)	(n=481)	(n=559)	(n=675)	(n=146)	(n=175)	(n=145)	(n=795)	(n=482)
	AP mech.	97.6*	509**	12.0	598.1	7294.1	275.4	917.9	-705.2	-29.9	995.8	359**	313**
	TP mech.	487***	-269.3	1012***	-1020.0	1134**	1509***	1032*	679.1*	-115.9	111.3	459**	1080*
Rice yield (kg/ha)		(n=1010)	(n=132)	(n=81)	(n=158)	(n=119)	(n=148)	(n=76)	(n=101)	(n=91)		(n=104)	
	AP mech.	362.1**	1027.6	705***	966***	-926**	1089*	743**	-149.4	59.6	-	378***	-
	TP mech.	677.8*	1309.9	639***	848***	923***	496.8	708***	967**	406.4	-	323***	-

Source: author's compilation.

Perhaps more importantly, findings further suggest that both animal-powered and tractor-powered mechanization have significant effects on the intensity of use of hired labor. While animal-powered mechanization increases the amount of hired labor by 2.5 adult equivalents in the Senegal, it reduces the amount of hired labor by 2.9, 3.7 and 4.4 adult equivalents in South Africa, Egypt and Niger respectively, *ceteris paribus*. Tractor-powered mechanization increase the amount of hired labor by 5, 2, 2, and 3 adult equivalents in the joint model, Ghana, Niger, and Zimbabwe respectively, *ceteris paribus*. Tractor-powered mechanization reduces amount of labor used in by about 4, 8, and 13 adult equivalents in Ethiopia, Senegal and Kenya respectively, *ceteris paribus*. This points to mechanization causing a shift towards off-farm work – which would induce labor-capital substitution due to the rise in land-labor ratio. This has been evident in countries where out migration from rural areas led to a rapid decline in farm labor. This, consequently, would lead to rising labor cost and thus demand for labor saving techniques, or mechanization (Diao et al, 2014; Diao et al., 2017). In the case of Niger, the negative and significant finding (with use of animal-powered mechanization) might imply that farmers who work off-farm are more likely to depend on income the off-farm activities and less likely to invest in buying bullocks and mules for production purposes. This might also imply that they are more likely to use tractors.

Finally, the effect of animal-powered and tractor-powered mechanization on maize and rice yield is evident. The use of animal-powered mechanization increases maize yield by 98kg/ha, 509kg/ha, 359kg/ha, and 313 kg/ha in the joint model, Burkina Faso, Zambia and Zimbabwe respectively. However, tractor-powered mechanization increases maize yield by 487kg/ha, 1012kg/ha, 1134/ha, 1509/ha, 1032/ha, 679/ha, 459/ha, and 1080 kg/ha in the joint model, Cameroon, Ethiopia, Ghana, Kenya, Niger, Zambia, and Zimbabwe respectively, *ceteris paribus*. The use of animal-powered mechanization increases rice yield by 362 kg/ha, 705 kg/ha, 966 kg/ha, 926kg/ha, 1089 kg/ha, 743 kg/ha, and 378 kg/ha in the joint model, Cameroon, Egypt, Ethiopia, Ghana, Kenya, and Zambia respectively. Tractor-powered mechanization increases rice yield by 487kg/ha, 1012kg/ha, 1134/ha, 1509/ha, 1032/ha, 679/ha, 459/ha, and 1080 kg/ha in the joint model, Cameroon, Egypt, Ethiopia, Kenya, Niger, and Zambia respectively, *ceteris paribus*.

6. Conclusion

This study examined the status, drivers and, consequently, the impacts of agricultural mechanization in eleven countries in Africa. Access to light hand-held tools and equipment remains the main type of machinery in most countries. About 48% of the sampled households have access to light machinery compared to 35% that accessed animal-powered machinery, and only about 18% that used tractor-powered machinery. More importantly, findings show variations in terms of access to these machinery by country – while light hand-held machinery is predominantly accessible in Cameroon (97%), Ghana (82%) and Zambia (81%) while animal-powered machinery is the main type of mechanization in Senegal (79%), Burkina Faso (69%) and Zimbabwe (65%). Tractor-powered machinery, as expected, is largely common in more developed counties like Egypt (90%) and South Africa (72%).

There are three possible ways of acquiring machinery; ownership by a single household (or farm), joint ownership with other households (or farms), and leasing from for own use or for joint use with other households. Findings show that light machinery and animal-powered machinery are mainly owned by individual households. A few households hire or rent medium-to-heavy machinery, in particular tractors, ploughs and threshers. To enhance access to these more expensive equipment, lease arrangements that favor the cash constraints small holder farmers would be more desirable.

Significant drivers of animal-powered mechanization include the gender of the household head, the size of the household (adult equivalent), participation in off-farm economic activities, distance to the input and output markets, farm size, land tenure (own-land and rented land and), type of farming system (shifting cultivation), access to extension services, and use of fertilizer and pesticides. However, land tenure (own-land), farming system (rotational cropping), irrigation, and number of household and hired laborers showed mixed evidence. Significant drivers of tractor-powered mechanization include household size, education level of the household head, off-farm activities, distance to the market, farming system (rotational cropping), access to extension services, farm income, fertilizer use, and pesticides use. However, use of irrigation and number of household laborers have mixed influences on the use of tractor-powered mechanization. The differences in the direction of the relationship between these variables and mechanization calls for country specific studies and tailored policies. Considering the local conditions and realities is important in increase uptake of farm mechanization.

This study finds that after controlling for socio-economic, demographic, and regional determinants, agricultural mechanization, significantly increases the amount of cropland cultivated (extensification) in the overall models by about 7ha and 51ha for animal-powered and tractor-powered mechanization. Furthermore, agricultural mechanization is accompanied by use of inputs and input intensification. On average, tractor-powered mechanization increases the amount of fertilizer by about 13kg/ha. Finding further suggest that both animal-powered and tractor-powered mechanization have significant effects on the use of household and hired labor. Animal-powered mechanization increases the amount of household labor by 2 adult equivalents, and the probability of using hired labor by about 20%. On the other hand, tractor-powered mechanization reduces the amount of household labor by 1.6 adult equivalents, and the probability of using hired labor by about 16%, and the amount of hired labour by 5.4 adult equivalents. Finally, the effect of animal-powered and tractor-powered mechanization on maize and rice yield is evident. The use of animal-powered mechanization increases maize and rice yields by 98kg/ha and 362kg/ha. However, tractor-powered mechanization increases maize and rice yields by 487kg/ha and 677kg/ha.

These findings point to the importance of developing favorable arrangements that would avail mechanization to small and medium scale farmers either through ADP or tractors. In places where tractors are inaccessible, ADP may serve as alternative farm power source. Efforts to deepen mechanization would involve providing incentives for private sector to scale agricultural mechanization initiatives and targeting and engaging both male and female farmers by investing in supportive infrastructure and farmer training at scale.

The mixed evidence on displacement or increased use of family and hired labor points to a need to carry out national rather than regional assessment to better inform policy. ADP and tractor powered mechanization reduces the amount of family and hired labor especially during land preparation but more labor would be needed in subsequent operations (such as weeding and harvesting). Mechanization also helps in timely land preparation and in cultivation of land that would have otherwise not been possible to cultivate due to seasonal labor shortages.

7. Limitations of the study

We would like to point out that the dataset is used in this study is nationally representative and comprehensive in capturing farm operations and covers many countries across Africa but is rather old – collected in 2004. Our results are very still very relevant, however, future studies should apply more recent data and if possible panel data to better capture the impacts.

The adopted the empirical model suggested by Teb and Trivedi which falls into the class of nonlinear, non-normal micro-econometric models of treatment and outcome with selection. It was developed and applied for studies in health care utilization (to examine the causal effect of managed care) but has recently been applied to machine learning, epidemiology and on impact of maize varietal choice among farmers. Availability of panel data would better measure impacts and also capture the drivers.

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9. Appendix

Table A1: Access to machinery, tools, and implements (average number per household)

	Machinery, Tools, and Implements Ownership (number per household)											
	Burkina Faso	Cameroon	Egypt	Ethiopia	Ghana	Kenya	Niger	Senegal	South Africa	Zambia	Zimbabwe	Total
Light Machinery												
Cutlass/ machete	2.8	4.8	0.9	1.5	3.7	14.2	1.7	2.2	1.3	0.5	0.3	3.1
Hoe	9.0	4.0	1.2	2.0	4.0	16.4	3.7	2.4	3.6	5.7	6.2	5.3
File	0.5	2.3	0.1	0.3	0.1	9.2	0.4	0.2	1.1	0.3	0.5	1.3
Axe	2.2	1.0	3.5	1.6	0.6	8.6	1.5	1.6	0.7	2.4	1.8	2.3
Baskets	3.4	9.2	1.5	13.7	4.0	22.1	1.7	2.0	7.8	0.8	0.7	5.8
Weeder	1.3	0.6	2.1	0.6	0.1	1.3	1.9	3.7	0.7	0.1	0.1	1.2
Others	1.2	1.4	1.1	0.7	0.4	11.7	1.3	0.9	1.9	0.3	0.4	1.8
Medium-heavy Machinery												
Tractor	0.0	0.0	0.6	0.1	0.1	0.2	0.0	0.0	2.2	0.1	0.0	0.2
Plough	0.9	0.0	0.9	0.4	0.1	0.3	0.2	0.4	1.3	0.3	0.9	0.5
Trolley/Trailer	0.6	0.0	0.1	0.0	0.0	0.2	0.1	0.2	1.3	0.1	0.0	0.2
Thresher	0.0	0.0	0.6	0.0	0.0	0.1	0.0	0.0	0.3	0.1	0.0	0.1
Fodder cutting machine	0.0	0.0	0.1	0.0	0.0	0.1	0.0	0.0	0.3	0.0	0.0	0.0
Generator/diesel pump	0.0	0.0	0.7	0.0	0.0	0.1	0.1	0.0	0.4	0.0	0.0	0.1
Spraying machines	0.3	0.4	0.1	0.0	0.2	0.8	0.1	0.0	0.6	0.1	0.0	0.2
Others	0.2	0.3	0.1	0.0	0.0	4.6	0.2	0.3	0.4	0.2	0.6	0.6
Farm animal power												
Bullocks	1.4	0.0	0.2	0.9	0.2	0.5	0.7	0.5	0.3	0.4	0.1	0.5
Mules	0.9	0.0	0.2	0.1	0.0	0.0	0.4	0.5	0.1	0.1	4.4	0.6
Others	0.0	0.0	0.3	0.4	0.0	2.6	0.2	1.0	0.0	0.1	0.3	0.5

Source: author's compilation.