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Improving Crop Yields in Sub-Saharan Africa: What Does the East African Data Say?

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Abstract

Recent micro level data from East Africa is used to benchmark aggregate data and assess the role of agricultural inputs in explaining variation in crop yields on smallholding plots. Fertilizer, improved seeds, protection against erosion and pesticides improve crop yields in Rwanda and Ethiopia, but not Uganda, possibly associated with lack of use there. With all positive yield determinants in place, wheat and maize yields could increase fourfold. The data hints at the negative effect of climate change on yields and the benefits of accompanying measures to mitigate its adverse impact (access to finance and protection against erosion). The adverse effect of crop damage on yields varies between 12/13 percent (Rwanda, Uganda) to 36 percent (Ethiopia). Protection against erosion and investment financing mitigate these effects considerably.

I. INTRODUCTION

It is well known that crop yields are much lower in sub-Saharan Africa compared to elsewhere in the world and this has led to the need for the Continent to import a large share of its food needs (UN 2015). The need to enhance the production and productivity of the agricultural sector is not only relevant for limiting the forex import requirements of the country. It can also ensure that the large number of working age people who will be entering the labor force on the sub-Saharan Continent over the next twenty years will be gainfully employed.

The weakness in the productivity of crops across Sub Saharan Africa is not only related to the poor soils in many countries (CIMMYT, 2015) but also to the limited use of essential inputs that are needed to raise the productivity level. These inputs include the use of improved seeds, fertilizers, irrigation, pesticides. The hypothesis is that the use of these inputs would boost the productivity of crops.

This paper uses household survey data in Ethiopia, Rwanda and Uganda to assess the extent to which inputs often quoted in general discussion have succeeded in improving crop yields in these countries. Previous work in this area has used time series data from FAO on crop productivity to assess the importance of various inputs. The results are quite wide ranging and in general provide muted support for the view that essential inputs significantly improve productivity. For example, Epule et al. (2018) find that the availability of tractors improve crop yields much more than irrigation and fertilizer in Uganda. Using micro data from agricultural surveys in Ethiopia over 2011–13, Mann and Warner (2016) find that crop damage coming from flooding, hail and pests, and terrain elevation have greater explanatory power in determining wheat yields in Ethiopia than irrigation and the availability of improved seeds. However, they identify significant effects at the 90 percent level of confidence for the use of fertilizer.

Another strand of literature has looked at the explanation for the large differences in agricultural productivity across countries (Gollin et al. (2002), (2014)). The general finding is that that the choice of crop matters more than the availability of inputs although for many countries in the middle sub-Saharan Africa belt, the productivity gap due to input usage is very large (Alvarez and Berg (2019), Adamopoulos and Restuccia (2018).

This paper is the first to our knowledge that uses micro data from household surveys in sub-Saharan Africa to assess the importance of inputs in affecting crop yields for a wide variety of crops. It also attempts to assess the role of a variety of factors in mitigating the adverse effects of climate change on crops, with climate change associated with damaging environmental effects on crops.

II.   AGGREGATE AND MICRO DATA CROP YIELDS

Before turning to micro data, we first take a look at what official data shows us in terms of crop yields of basic crops in these countries in recent years (Table 1). The table also includes a few other countries in the East African region and a continental leading performer (South Africa). The most recent datapoint chosen corresponds with the timing of the most recent household survey.

Table 1. Agriculture Yields (Kilogram per hectare)									
2011	2017	2011	2017	2011	2017	2011	2017	2011	2017
Maize		Sorghum		Cassava		Pulses		Wheat	
Ethiopia 2954	3675	2054	2525	20441	no data	1433	1485	2029	2813
Malawi 2248		818		21567		890			
Mozambique (2010) 1050		500		9390		644			
Rwanda 1742	1540	1820	1403	1364	13551	904	868	no data	1325
Tanzania 2218		1548		5323		1235			
Uganda 1244	1635	1355	900	6204	6500	689	950	no data	no data
South Africa	5800								2900

Sources: Pauw et al. Agriculture and Poverty Growth Reduction in Mozambique, 2011; Statistics Rwanda, Central Statistics Office, Ethiopia, Statistics Tanzania, Statistics Uganda, Tugendhat, USAID, FAO.

In Rwanda, yields have remained fairly stable over 2011–17 except for the drastic improvement in the yield for cassava, associated with a better understanding of the plot size used in cultivation and better control over the cassava brown streak disease (FAO, 2019). For Ethiopia, maize, sorghum and wheat yields have shown significant improvements with the wheat yield now close to South Africa. For Uganda, the picture is mixed with improvements in maize and pulse yields and an apparent deterioration in the sorghum yield.

The micro data chosen for this paper comes from the most recent household surveys, all of which have agricultural modules. Rwanda's most recent survey EICV5 covers 2016/17; the corresponding survey from Ethiopia is the 2015/16 LSMS and the 2015/16 national panel survey is used for Uganda. The population samples generally capture the smallholder because of difficulties accessing data from large farms. In Rwanda, the median farm is only a quarter of a hectare in size while in Uganda, the median farm is 0.5 hectares and in Ethiopia, the median farm is larger at 1.1 hectares.[1]

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[1] For Ethiopia, this figure is in the range of Taffesse's estimates (2013)

We focus on the yields for the major crops and legumes namely maize, sorghum, beans, wheat and add soybeans for Rwanda, teff for Ethiopia, and cassava for Uganda.[2] These crops and legumes correspond to roughly 60 percent of the cultivated area in Rwanda and about 86 percent in Ethiopia (2015/16 estimate).

The yields per hectare for the major crops and legumes in Rwanda are extremely similar except for soybeans (Figure 1). The mode generally peaks at 1000–1500 kilograms per hectare. Moreover, there is similarity between the aggregate national yields for the various foodstuffs in 2017 with those estimated from the micro data (median estimate) as shown in Table 2. The correspondence is close except for the beans category which appear to be much more productive in the micro sample.

Figure 1. Rwanda Crop Yields, 2016–17
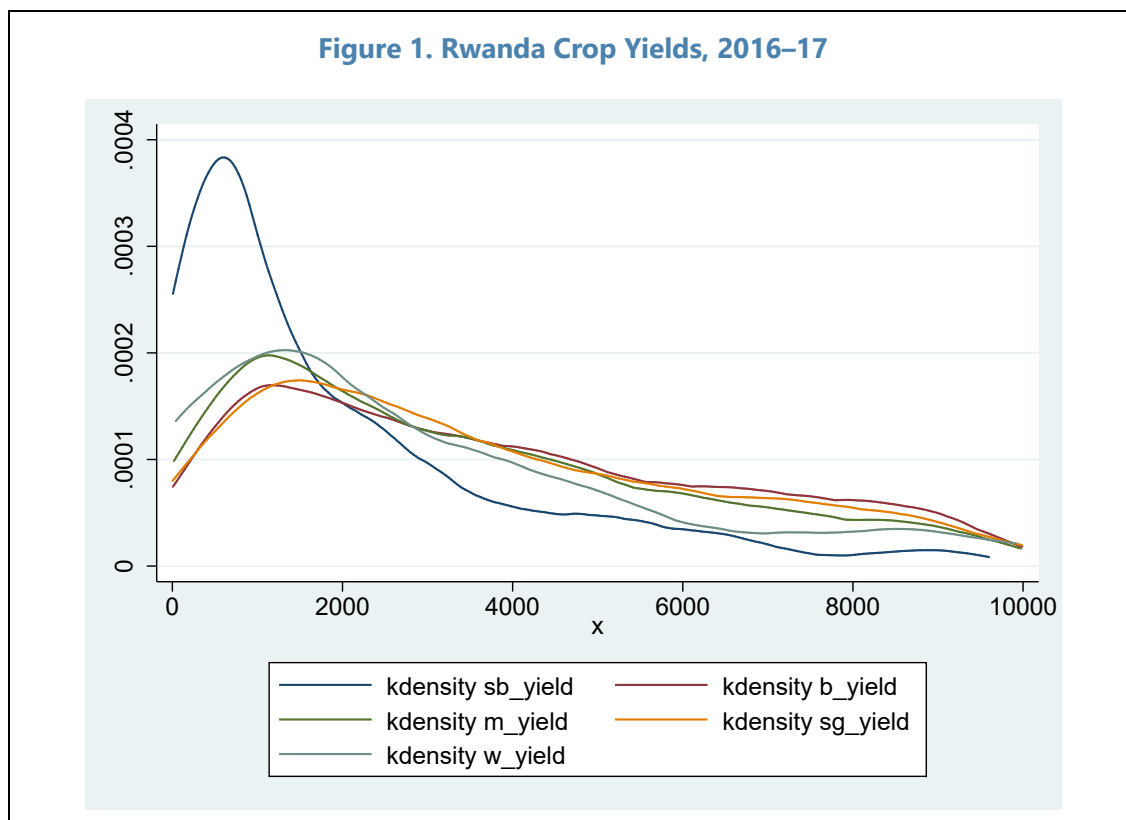
The correspondence between the micro and macro farm yield data is weak for Ethiopia, with the micro data showing yields less than half those of the aggregate data reported in FAO databases. Part of the reason could be the smaller size of farm holdings in the micro surveys, but validation of Ethiopia FAO data may also play a role, since it is based on imputation rather than actual production. This is a warning for researchers that make explicit use of FAO data. For Uganda, the correspondence between the micro and macro data is close with only the yield for cassava showing a significant difference between the two sources of data.

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[2] Cassava is also a major crop in Rwanda but it is difficult to distinguish between the surface area of the field and the amount of the field used for cultivation and therefore it is excluded from the micro analysis.

Notwithstanding some differences in the levels of the yields in the micro data compared to the aggregate data, the relative ranking across crop categories matches strongly for both countries taking out the bean category. The only case where the ranking differs is for sorghum in Rwanda which is placed as the most productive drop in the micro data but is less productive than maize in the aggregate data.

Table 2. Yield Comparison Between Aggregate and Micro Data

(Kilograms per hectare)

	Rwanda		Ethiopia		Uganda	
	Aggregate Data	Micro Data	Aggregate Data	Micro Data	Aggregate Data	Micro Data
Maize	1540	1751	3675	1911	1635	1451
Sorghum	1403	1868	2525	1249	900	753
Wheat	1325	1475	2813	1534		
Beans	818	1862	1485	1201	950	931
Soybeans	646	1217				
Teff			1408	1030		
Cassava					6500	3271

Sources: Country household surveys plus data sources from Table 1.

Figure 2. Ethiopia Crop Yields, 2015–16

Figure 3. Uganda Crop Yields, 2014–15
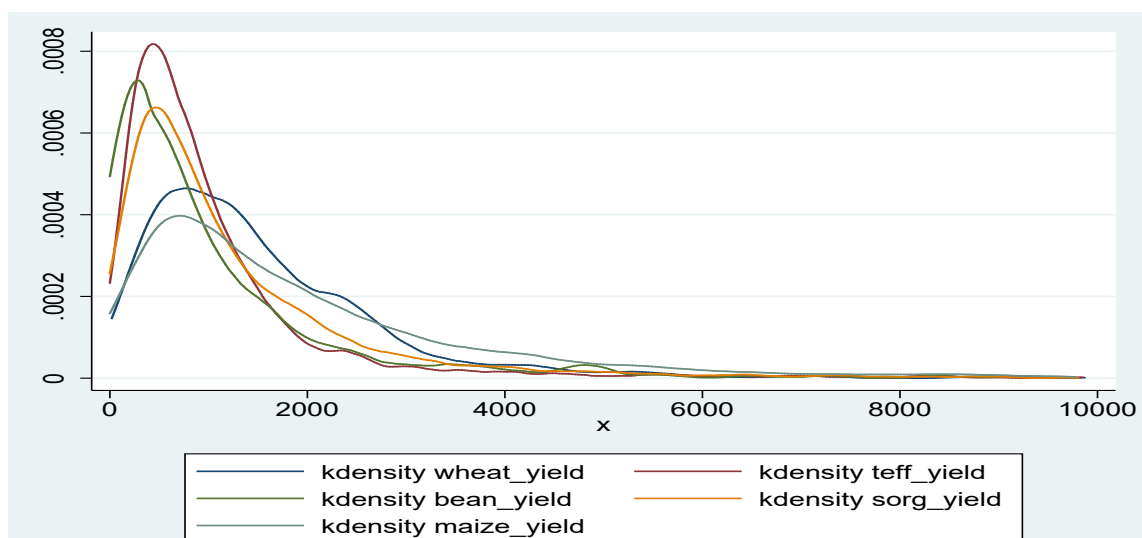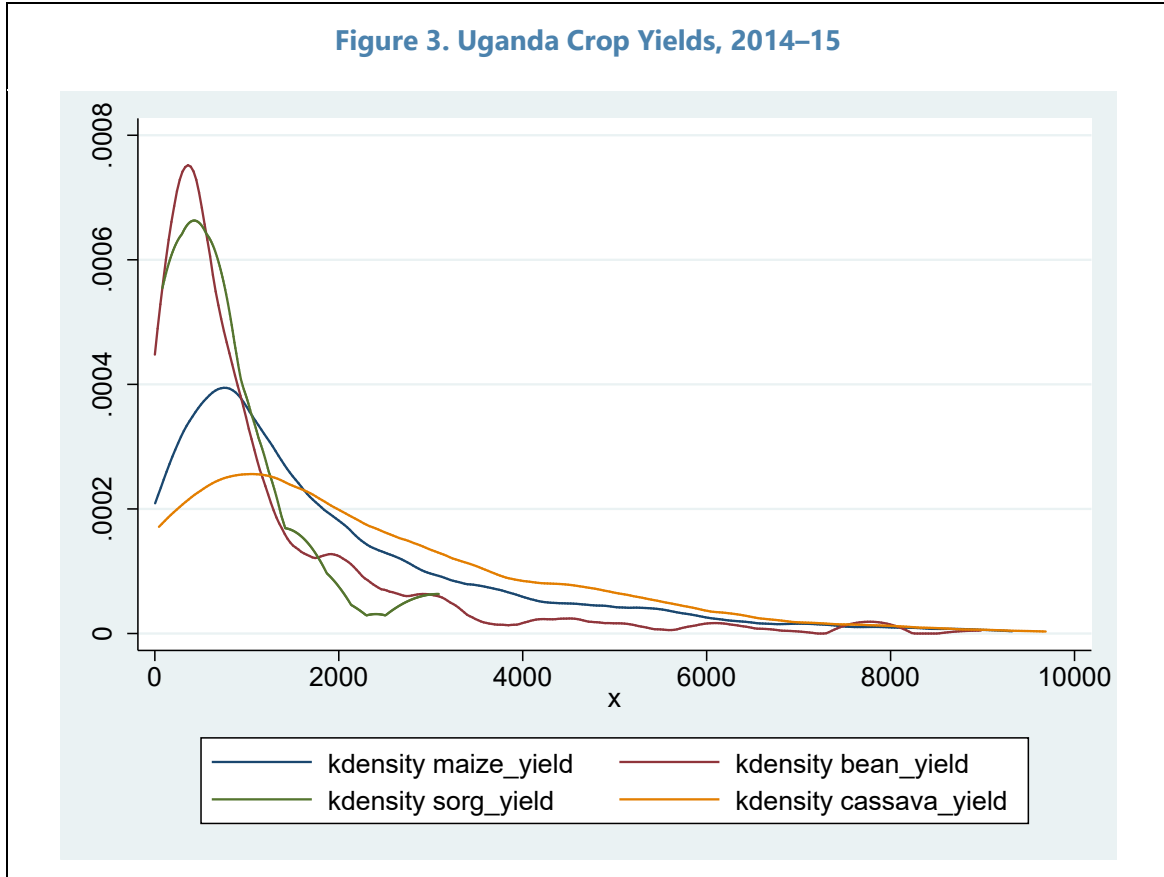
III.   DETERMINANTS OF CROP YIELDS

Having shown comparability between the micro and aggregate data, at least in terms of rankings of yield crops, we take the opportunity to assess yield determinants. Explicitly, we aim to assess whether yields recorded in the micro data are significantly related (in a statistical sense) to the standard determinants emphasized in the literature. The availability of inputs is a strong determinant of yields in emerging market and industrial countries and this section attempts to uncover whether we can identify similar relationships in micro data in a sample of East African countries (see Mcarthur and Mccord (2017) for a typical example of yield determinants in developed countries). The standard inputs included in this analysis are the availability of fertilizer, insecticide, improved seeds, irrigation, and protection against erosion, all defined as binary dummy variables. We have also included a number of controls for the countries: region dummies, degree of urbanization, specific crop and legume dummy variables, crop failure associated with climate shocks; and soil quality, slope and elevation of the terrain specifically for Ethiopia and Uganda. Finally, we include gender and proprietorial variables - female farmers and land title holders.

A. Rwanda

The basic regression for Rwanda shows very strong results for the availability of insecticide, improved seeds and the presence of irrigation while the availability of fertilizer is not significant at standard confidence levels. For example, the availability of insecticides raises crop yield by about 47–49 percent. Protection against erosion has a significant positive impact on yields at the 95 percent level of confidence while crop damage impacts negatively on yields. In terms of location variables (not shown), the Eastern province of Rwanda appears to be the most productive region while the Southern province is the least productive region. Proximity to urban areas has a strong positive effect on the agricultural yield which is surprising given that cities are not normally built on the most fertile land, but it may reflect farmer quality.

The two variables linked to economic circumstance are strongly correlated with the yield profile. Females who run the plots generally experience less productive yields compared to males while ownership conveys a strong boost to the productivity of the plot, likely associated with the fact that ownership motivates performance. The size of the plot has a significant negative effect on the yield and is more than 1 for 1 so that larger plots produce smaller quantities ceteris paribus (see section VI for a deeper discussion on the role of farm size on welfare).

One of the issues in econometric analysis is omitted variable bias because it leads to biased estimates of the included coefficients in the analysis. An obvious factor excluded from the analysis of crop yields is farmer quality because of the difficulty in measuring it. One aspect of farmer quality is related to his education and literacy level. We measure literacy as a dummy variable for the ability to read or write while education is measured via dummy variables for the highest level of education achieved-primary, lower secondary, upper secondary, or university level education. Column 2 reveals that the level of literacy is a positive determinant of the crop yield but not significant while those with lower and upper secondary education have significantly higher yields compared with the rest of the population. The introduction of these variables has virtually no effect on the value of the coefficients of the other variables.

The Heckman approach is an alternative way of modeling the unknown farmer quality by correcting for the possibility of omitted variables and/or sample selection issues.[3] A proxy variable is used to capture farmer quality and is related to various determinants in a first stage and the error term from this first stage regression is entered as an unknown variable in the second stage. We postulate a relation between the literacy rate and farmer quality and relate it to the level of education and the log age level of the household representative.
This relationship is estimated via maximum likelihood in a first stage and the covariance of the error term with that of the second stage error is tested for significance (inverse Mills

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[3] Wooldridge, J. (2009) discusses a similar application in the context of the determinants of firm productivity.

ratio). If the error term capturing the unknown farmer quality is unrelated to the error term from the second stage regression, there is no evidence of omitted variable bias and the OLS estimates are appropriate.

Since the Chi squared term in column [3] of Table 3 is insignificant, this suggests that the specification does not suffer from omitted variable bias and therefore the OLS estimates in column [2] are appropriate. As a final test of the stability of the estimates, we restrict the sample to those aged less than 66. Interestingly, in this case, the fertilizer variable becomes significant, irrigation becomes insignificant while the other variables remain almost unchanged.

Table 3. Determinants of Yields Using Household Survey Data
(Log kilogram yield per hectare)

	Rwanda			
	OLS	OLS	Heckman	OLS
Fertilizer	0.06	0.04	0.12 *	0.23 ***
Insecticide	0.49 ***	0.47 ***	0.45 ***	0.42 ***
Improved seeds	0.09 ***	0.08 ***	0.11 ***	0.19 ***
Irrigation	0.12 **	0.12 **	0.13 *	0.07
Protection against erosion	0.07 **	0.07 **	0.05	0.05
Crop damage	-0.13 ***	-0.12 ***	-0.12 ***	-0.13 ***
Urban	0.35 ***	0.35 ***	0.32 ***	0.39 **
Female farm owner	-0.18 ***	-0.18 ***	-0.18 ***	-0.12 ***
Land title holder	0.15 ***	0.15 ***	0.06 **	0.06 **
Surface area of plot (log)	-1.61 ***	-1.61 ***	-1.66 ***	-1.64 ***
Literacy		0.02		0.05
Primary ed.		0.02		0.01
Lower sec. ed.		0.26 ***		0.25 ***
Upper sec. ed.		0.24 ***		0.27 ***
College ed.		0.13		0.13
R^2	0.36	0.36		0.38
Wald Chi^2			5409 ***	
Test of error term indepdendence (Chi^2)			0.56	
Number of observations	17332	17332	17332	10062

Sources: Rwanda household survey 2016/17 and IMF staff estimates.

B. Ethiopia

In Ethiopia, each input variable is significant except for the use of irrigation techniques. Moreover, the variable capturing soil quality has a significant positive influence on crop yields while less than complete utilization of the agricultural plot lowers the yield. Difficult growing conditions also adversely affect crop yields as well as urbanized settings. Controlling for the other characteristics, Gambella is the most productive region while the other regions are insignificantly different from each other.

The Ethiopia data also contains information on the elevation of the plot and the slope of the plot. In line with previous research we split the effect of elevation at the 2000 meter mark and this adjustment reveals a reduction in yields up to the 2000 meter mark and a significant rise in yields subsequently. For the slope of the terrain, the effect on yields is insignificant. The elevation variables may be capturing the strong yields recorded in some upland areas and this finding is consistent with the work of Mann and Warner for wheat crops. As expected, plot size is inversely related to yields while larger farm holdings are associated with lower productivity, controlling for the specific field size. In contrast to Rwanda, the administration of the plot by a female significantly improves the yield of the plot and land title ownership also positively influences the yield. Similar to the analysis on Rwanda, we proxy the quality of the farmer by his education and literacy level, but these variables have no effect on yields (Column 2). Notwithstanding the rich variety of explanatory variables for Ethiopia, the explanatory power is considerably weaker than for Rwanda, leaving open the possibility of future analysis to improve fit.

Table 4. Determinants of Yields Using Household Survey Data

(Log kilogram yield per hectare)

	Ethiopia			
		with education	Heckman	
Fertilizer	0.29 ***	0.29 ***	0.01	0.28 ***
Insecticide	0.36 ***	0.36 ***	0.34 ***	0.44 ***
Improved seeds	0.45 ***	0.45 ***	0.45 ***	0.46 ***
Soil quality	0.15 ***	0.15 ***	0.08 ***	0.15 ***
Irrigation	-0.08	-0.08	0.12	-0.03
Protection against erosion	0.11 ***	0.11 ***	0.41 ***	0.09 ***
Crop damage	-0.36 ***	-0.36 ***	-0.26 ***	-0.33 ***
Low elevation	-0.1	-0.11 **	-0.08	-0.02
High elevation	0.86 ***	0.86 ***	0.26 *	0.93 **
Moderate terrain slope	0.06	0.06	0.03 **	0.01
Steep terrain slope	-0.06 *	-0.06 *	-0.01 ***	-0.08 **
Urban	-0.46 ***	-0.48 ***	-0.44 **	-0.49 ***
Female farm owner	0.12 ***	0.12 **	-0.1	0.08 *
Land title holder	0.18 ***	0.17 ***	0.13	0.14 ***
Surface area of plot (log)	-0.16 ***	-0.16 ***	-0.19 ***	-0.16 ***
Surface area of farm holding (log)	-0.07 ***	-0.07 ***	-0.19 ***	-0.07 ***
Literacy		0.03		0
Primary ed.		-0.04		-0.02
Lower sec. ed.		-0.04		-0.2
Upper sec. ed.		0.04		0.1
College ed.		0.29		0.39
R^2	0.14	0.14		0.14
Wald Chi^2			656.8 ***	
Test of error term indepdendence (Chi^2)			0.87	
Number of observations	10925	10925	10521	9041

Sources: Ethiopia 2015/16 LSMS and IMF staff estimates.

Turning to the Heckman approach for measuring the possibility of omitted variables, we postulate that the use of agricultural extension programs is related to farmer quality and relate

its use to the level of education, the availability of a tractor, whether a field was left fallow in the past and the age level of the household representative. Column 3 shows the maximum likelihood estimates from the Heckman procedure and the test statistic for the inverse Mills ratio. The Chi squared test of the independence of the error terms is insignificant revealing that OLS is an appropriate specification of crop yield determinants controlling for possible farmer quality bias, at least when proxied by use of agriculture extension services.

C. Uganda

For Uganda, the input variables are generally insignificant while poor soil quality and crop damage related to erosion have significant negative impacts on yields. Common with Rwanda, the ownership of a plot of land conveys a productive boost with a similar coefficient estimate. Moreover, comparable to Rwanda, extremely large diseconomies of scale are associated with bigger plots and urban plots elicit a positive boost to productivity compared to those in rural areas. The addition of education and literacy variables improves the explanatory power of the relationship with literacy a strong positive determinant of yields and upper secondary education the least negative determinant. Perhaps surprisingly, those with college education experience yields that are 35 percent lower than secondary school educated farmers, possibly suggesting that the choice of farming is a last resort for these individuals.

For the Heckman approach, the use of extension services is chosen as the proxy for farmer quality. Given the significance of the error term, it appears that this is the correct choice for the estimator. In terms of the variables of interest, the use of inputs remains insignificant. The only major coefficient change is the large positive estimate for upper secondary education. Finally, little change in coefficient estimate sizes is found when the sample is restricted to those aged between 15 and 65 (Table 5, column 4).

Table 5. Determinants of Yields Using Household Survey Data
(Log kilogram yield per hectare)

|	Uganda			
	OLS	OLS	Heckman	Heckman
Fertilizer	0.04	0.02	0.04	0.11
Insecticide	0.12	0.13	0.11	0.13
Improved seeds				
Poor soil quality	-0.17 ***	-0.19 ***	-0.16 ***	-0.16 ***
Irrigation	-0.04	-0.03	-0.05	0.01
Crop damage	-0.14 *	-0.16 *	-0.14 *	-0.11
Urban	0.13 *	0.14 **	0.15 **	0.12
Female farm owner	-0.05	-0.01	-0.02	0.02
Land title holder	0.13 **	0.12 *	0.13 **	-0.01
Surface area of plot (log)	-1.5 ***	-1.51 ***	-1.5 ***	-1.48 ***
Literacy		0.26 ***		
Primary ed.		-0.12 **	0.05	0.06
Lower sec. ed.		-0.12	0.05	0.15
Upper sec. ed.		-0.03	0.18 **	0.21 **
College ed.		-0.35 ***	-0.19 *	-0.16
R^2	0.58	0.59		
Wald Chi^2			3002 ***	2129 ***
Test of error term indepdendence (Chi^2)			5.77 **	5.73 **
Number of observations	2126	2126	2532	2016

Sources: Uganda National Panel Survey 2015/16 and IMF staff estimates.

IV. RELATIONSHIP BETWEEN SURFACE AREA AND YIELDS

One of the striking features of the regression results is the extremely strong negative relationship between plot yields and the surface area of farms. This negative relationship is shown clearly in the following scatter diagrams between the log surface area and log yield for the three countries. This relationship has been ascribed to mismeasurement on both the estimation of production and the surface area of plots. However, given the extremely strong

relationship shown in all three charts below, any cleaning method is unlikely to fully eliminate the negative relationship (see section VI for a deeper discussion of the issue).

Rwanda

Uganda

Ethiopia
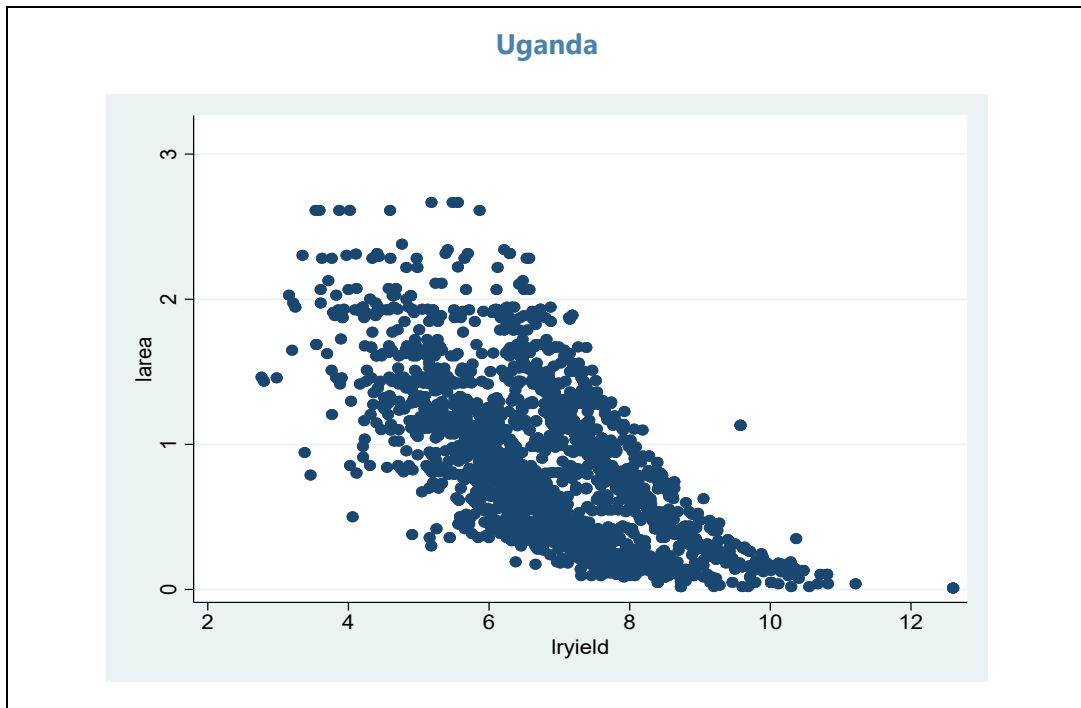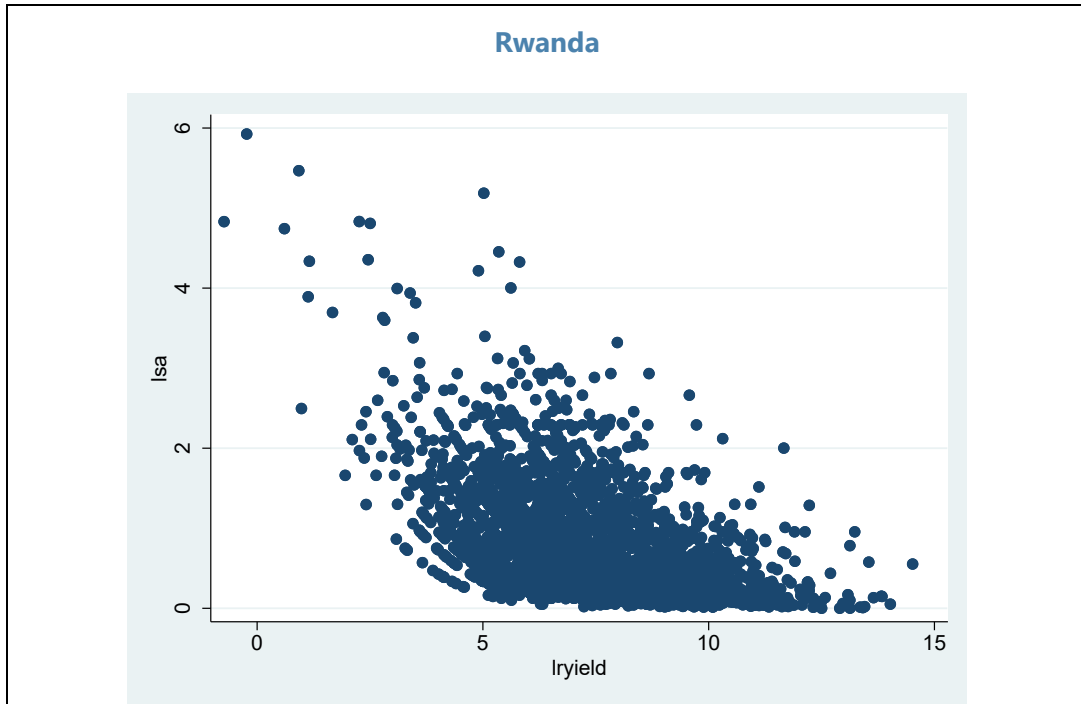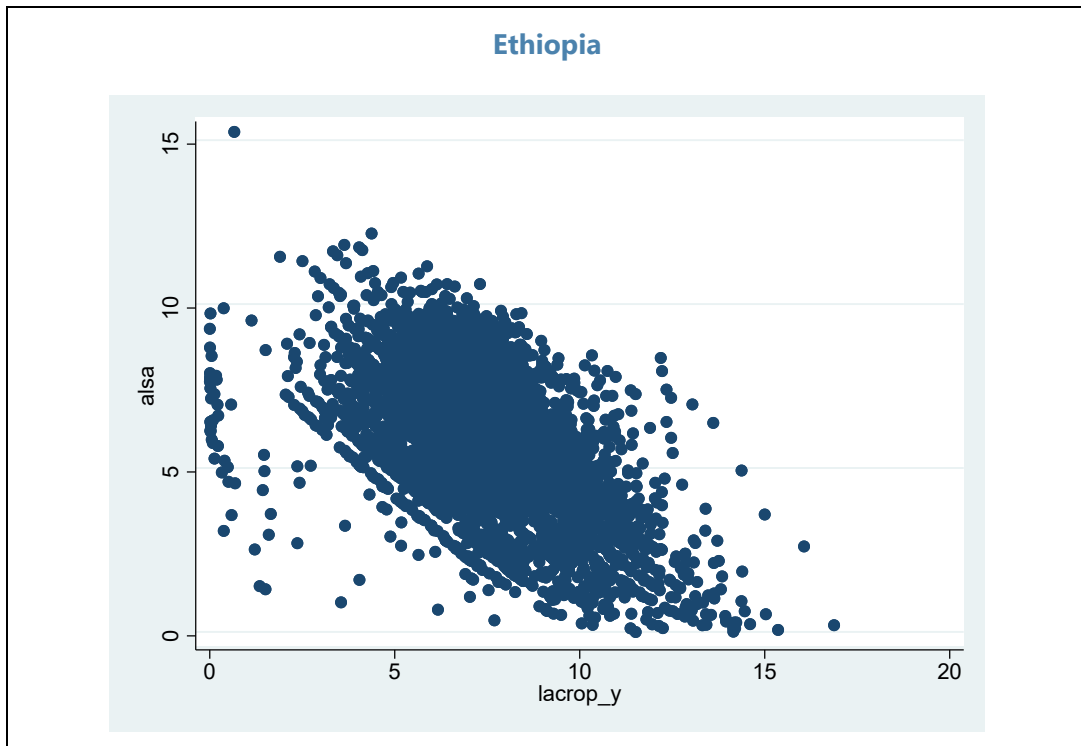
V.   USE OF AGRICULTURE INPUTS AND FRONTIER ESTIMATES

Given the significance of the various inputs, the question remains whether they are being applied in appropriate quantities. We took a look at the fertilizer quantities being used in Ethiopia and the amounts broadly correspond with the recommended amounts from the literature. For example, Wortmann and Sones (2017) have shown that the yields of wheat, maize, sorghum and teff improve with a fertilizer application of up to 80 kilos per hectare, but higher amounts do not yield significant improvements. The median estimate for usage of urea and dap in Ethiopia is about 90 kilos per hectare, quite close to recommended levels. This finding contrasts with Saweda et al. (2018) who document fertilizer application far above desired levels in many regions in Nigeria.

Use of inputs is also fairly prevalent in Ethiopia and Rwanda, although less so in Uganda. Table 5 shows the percentage of households using inputs. The figures for Ethiopia and Rwanda are comparable: the use of irrigation and erosion protection are similar while more Rwandan households use insecticide and improved seeds and Ethiopian households prefer fertilizer. Given the strong impact of insecticide and use of improved seeds in Ethiopia, there is a clear need to ramp up the availability of these inputs. The lack of significance of the irrigation variable in Ethiopia could be related to its lack of use in these samples so that there is not a minimum mass to produce significant results. Indeed, for Uganda, input usage is in general much lower than for the other two countries and this fact could also explain the insignificance of these variables in the Uganda regressions.

Table 6. Usage of Inputs into Improving Crops Yields			
(Percent of total household population)			
	Rwanda	Ethiopia	Uganda
Fertilizer	42.2	52.2	11.3
Insecticide	27.2	11.2	4.3
Improved seeds	28.5	5.5	
Irrigation	4.1	2.9	1.2
Protection against erosion	73.3	58.9	6.2
Sources: Household survey data and IMF staff estimates.			

Finally, we consider the possible production frontier available to small holders by assuming that all of the inputs are available, that the plot is a third of a hectare on a 1 hectare farm holding with no crop damage associated with adverse weather conditions. In Ethiopia, we assume that the farmer type is a female landowner who is literate and college educated. The same applies to Rwanda except that we assume a male farmer. For Uganda we assume a male, high-school educated land title holder. Based on these assumptions, we obtain a maize yield per hectare of 7300 kgs in Ethiopia, 7900 kgs in Rwanda and 7644 kgs in Uganda. For wheat, the estimated yields are 6700 kgs in Ethiopia and 5400 kgs in Rwanda. These results suggest that the potential exists to achieve much higher yields in all three countries assuming the availability of inputs.

VI. MEASUREMENT ERROR

There have been concerns expressed that the use of micro survey data from African countries is problematic because of the presence of large measurement errors. This argument is most often made in the context of the negative relationship between plot yields and plot surface area documented clearly in section IV. A recent paper by Abay et al. (2019) has shown that both yields and surface area observations from micro data contain sizeable non-classical measurement errors but, interestingly, when both variables enter into a regression, their biases cancel each other out to a large extent.

To assess the information content of our yield variable and the importance of farm size in influencing welfare, we assess whether both variables demonstrate explanatory power in a standard regression of household consumption determinants. The idea is that stronger yields and larger farms should, ceteris paribus, support consumption expenditure. The standard determinants of household consumption include dummy variables for economic situation,

industry, region, gender, education, age and household size. We add title ownership, the average plot yield and the farm size for each household to assess whether these variables provide significant additional explanatory power.

Table 7. Consumption Determinants Using Household Survey Data

(Log household consumption)

	Ethiopia		Rwanda	
	Total Cons	Food cons	Total Cons	Food cons
Yield	0.03 ***	0.03 ***	0.06 ***	0.04 ***
Yield for non-farm worker	0	0	-0.02 ***	-0.03 **
Surface area of plot (log)	0.14 ***	0.14 ***	0.14 ***	0.05 ***
Land title holder	0.14 ***	0.16 ***	0.05 ***	-0.04
Farm worker	-0.08 ***	-0.06 ***	-0.28 ***	-0.15 ***
Non-farm worker	0.15 ***	0.08 **	0.13 **	0.25 **
Age	-0.02	-0.06 **	0.06 ***	0.01
Urban	0.37 ***	0.26 ***	0.24 ***	0.28 ***
Female farm owner	-0.02	0.01	-0.08 ***	-0.18 ***
Household size	0.62 ***	0.63 ***	0.66 ***	0.73 ***
Unemployed	-0.05 **	-0.04	-0.05	-0.06
Student			-0.08 **	-0.21 ***
Literacy	-0.03 *	-0.08 **	0.11 ***	0.1 ***
Primary ed.	0.12 ***	0.13 ***	0.05 **	0.07
Lower sec. ed.	0.14 ***	0.16 ***	0.27 ***	0.19 ***
Upper sec. ed.	0.18 ***	0.2 ***	0.49 ***	0.46 ***
College ed.	0.01	-0.16	1.04 ***	0.73 ***
R^2	0.35	0.31	0.47	0.2
Number of observations	8599	8599	4500	4500

Sources: Household survey data and IMF staff estimates.

For Rwanda, the results show a large disparity between household consumption for agricultural workers and non-farm workers at about 40 percent. Moreover, a positive age consumption profile exists. For the education variables, a strong education earnings/consumption profile is visible with college educated families consuming twice the amount of primary educated families. Literacy also has a positive bearing on consumption while student status lowers family consumption. The level of consumption in the capital city

Kigali is about 60 percent higher than in other areas while female headed households consume about 8 percent less than male headed households.

Turning to the variables related to agricultural production, land ownership yields a significant positive boost to consumption while stronger yields also boost production. Interestingly, the effect is larger for farmers than for those employed outside agriculture. Finally, farm size also boosts consumption. In terms of comparative magnitudes, a one standard deviation increase in yields would raise consumption by 7.5 percent while a corresponding increase in surface area would raise consumption by almost 15 percent. Therefore, notwithstanding the negative relationship between yields and plot size, larger farm holdings provide significantly larger boosts to welfare than higher yields.

In the Ethiopian case, the disparity between agricultural workers and non-farm workers is about 23 percent while no age consumption relationship exists. For education, a positive education earnings/consumption profile exists through college level but there is no college premium and literacy has a negative relationship with consumption. Families in urban settings consume about 37 percent more than in rural areas but there is no difference between female and male headed households.

On the variables of interest, strong yields raise consumption but with similar effects for farmers and other workers. Ownership of a farm plot conveys a 14 percent rise in family consumption while larger farm holdings also raise family consumption. Once again, in terms of comparative magnitudes, a one standard deviation increase in yields would raise consumption by 3.2 percent while a corresponding increase in surface area would raise consumption by 14 percent. Therefore, it is clear that yield performance has a stronger impact on consumption in Rwanda compared to Ethiopia but larger farms dwarf the impact of yields on household welfare.

VII.   CLIMATE EFFECTS

Household data can also provide a micro view of the way that climate change is menacing the development of agriculture in the sub-continent. The following table shows the extent of crop damage associated with changing weather patterns. Almost 40 percent of farmers have been affected by crop damage during the agricultural season in Ethiopia and Rwanda. Moreover, 70 percent of the farmers attribute the crop damage to climate change with an additional 10-20 percent associating crop damage with erosion and crop disease. For Uganda, the figures are less dramatic, but this may relate to the fact that the question was focused on the effects of erosion rather than on climate shocks more generally.

Table 8. Crop Damage
(Percent)

	Rwanda 2017	Ethiopia 2017	Uganda 2015
	38	38	8.5
Type of damage			
Change of climate			
(too much/little rain)	72.2	66	49.1
Landslide	6		
Erosion/insects/crop disease	10.2	21.8	47.2
destructive rains/hail	5.5	5.2	
Loss of soil fertility	6.1	2.7	0.3
Other		4.3	2.6

Sources: Household survey data and IMF staff estimates.

We have already determined that crop damage adversely affects crop yields, but the quantitative impact is severe. Crop damage causes a reduction in yields of between 13 percent in Rwanda and 52 percent in Ethiopia (Table 9). Given that about half of the population of the East African countries (Ethiopia 45 percent, Rwanda 54 percent) refer to themselves as farmers with farming as the only source of income, this is a very large effect on family welfare. Measures can help to reduce this impact such as establishing protection against erosion and obtaining access to finance. Indeed, protection against erosion reduces the impact of crop damage on yields by 16 percent in Ethiopia.

Access to finance is an additional tool that can be used to improve crop yields and mitigate crop damage through additional investment. The access to finance variable measures whether a household took out an investment loan in the past year. In the Ethiopia sample only about 27 percent of the population has access to loan financing whereas the figure jumps to 77 percent in the Rwanda sample. Interestingly, the variable is highly significant in Rwanda and improves yields by almost 25 percent although it does not seem to impact yields in Ethiopia. While the interaction of access to finance and the crop damage variable is negative, those with access to finance have better yields than those without any financial access ceteris paribus since the sum of the two access to finance variables is positive. Therefore, those families suffering crop damage in Rwanda but with access to finance can mitigate the effect of crop damage on yields by 6 percent.

The impact of input use to strengthen crop yields in both countries is formidable and is strengthened when we isolate related weather susceptibilities. For example, when we isolate the impact of climate damage through heat exposure, the impact of the use of irrigation becomes more important in Rwanda, almost doubling its impact by raising yields from 12 percent to 19 percent. However, no noticeable change is found for Ethiopia.

Table 9. Determinants of Yields Using Household Survey Data

(Log kilogram yield per hectare)

	Ethiopia		Rwanda	
		Too much heat		Too much heat
Fertilizer	0.3 ***	0.3 ***	0.1	0.1
Insecticide	0.37 ***	0.36 ***	0.47 ***	0.46 ***
Improved seeds	0.45 ***	0.44 ***	0.08 ***	0.07 **
Irrigation	-0.08	-0.1	0.12 **	0.19 ***
Protection against erosion	-0.01	0.03	0.12 ***	0.13 **
Access to investment finance	0.01	-0.01	0.25 ***	0.25 ***
Crop damage	-0.52 ***	-0.58 ***	-0.17 ***	-0.13 **
Interaction terms with crop damage				
Protection against erosion	0.16 **	0.08	-0.11 **	0.02
Investment Access	-0.08	0.04	-0.16 ***	-0.19 ***
Control variables				
Soil quality	0.13 ***	0.1 ***		
Female farm owner	0.12 ***	0.13 ***	-0.17 ***	-0.16 ***
Land title holder	0.18 ***	0.2 ***	0.15 ***	0.14 ***
R^2	0.15	0.16	0.36	0.37
Number of observations	10925	10445	17332	15059

Sources: Ethiopia and Rwanda household surveys and IMF staff estimates.

VIII.   CONCLUSION

This paper has used recent micro level data from a few East African countries to benchmark the validity of aggregate data and assess the role of agricultural inputs in explaining variation in crop yields on smallholding plots. Aggregate yield data for Rwanda is, if anything, below the micro data estimates while the opposite relationship holds for Ethiopia. For Uganda, the two data estimates are close except for cassava. In terms of relative yield rankings across the crop categories, the relationship between the micro and macro data is close except for beans in Rwanda.

Turning to the effectiveness of inputs, regression analysis shows that fertilizer, improved seeds, protection against erosion and pesticides all help to improve crop yields. Irrigation has a significant positive effect on yields in Rwanda but not in the other two countries, possible associated with lack of use. Moreover, with all positive yield determinants in place, wheat and maize yields could increase fourfold in Ethiopia, Rwanda, and Uganda.

While this paper has demonstrated significant benefits of using inputs for improving crop yields, it has not shown whether it is economically viable to do so. This would require a randomized experiment given the limited information on input costs in welfare surveys. More of this type of analysis is needed before concluding that the use of more inputs is the solution to the poor agricultural performance in Sub Saharan Africa. However, a case can be made to improve seed allocation through an effective seed regulatory framework. This framework should also establish a reliable and internationally acceptable seed certification system and should consider ways to boost the growth of the domestic seed industry.

Finally, the data provides a snapshot of the possible effect of climate change on yields and the benefits of accompanying measures to mitigate its adverse impact (access to finance and protection against erosion). The adverse effect of crop damage on yields varies between 12/13 percent (Rwanda, Uganda) to 52 percent (Ethiopia) and protection against erosion and investment financing can mitigate these effects to a large degree although the effects differ across countries. A possible policy solution to address some of the problems of climate change is to switch crop varieties and plant those that are more resistant to the adverse effects of climate change.

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