Agricultural Productivity and Farm Size in Selected East and Southern African Countries: Uganda, Tanzania and Malawi

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Motivation (1)

- Agricultural **productivity** plays a **leading role** in the economic growth of many developing countries (World Bank, 2008)
- **Increasing farm productivity** an important strategy to promote the agricultural sector while contributing to poverty alleviation
- **Challenges** to agricultural productivity growth: land quality and availability, labor and liquidity constraints, inadequate investment on research and extension, infrastructure and human capital, information, climate change (Hazell, 2007)
- **Environmental degradation** and **climate change** expected to impact the productivity of small-scale farms more severely than large farms (Hazell & Rahman, 2014)
- **Smallholder farming** prevalent in Sub-Saharan Africa (SSA) (Livingston, Schönberger, & Delaney, 2014)

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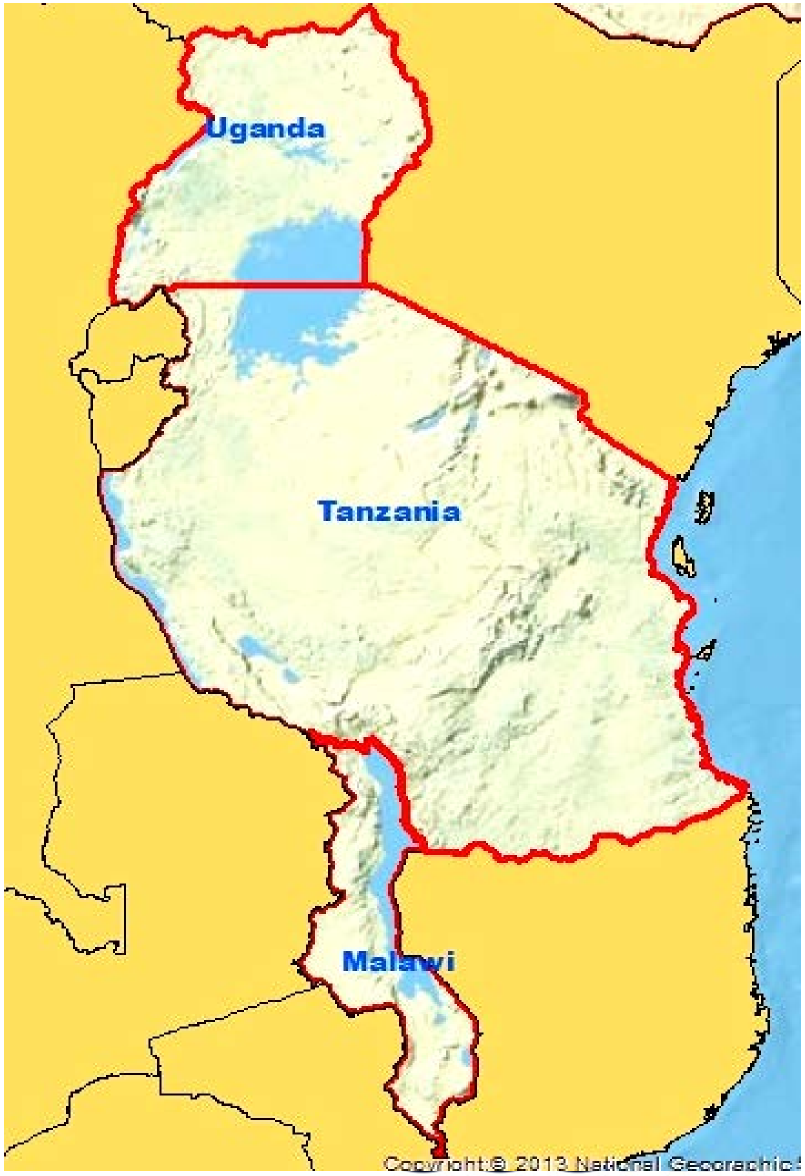
Motivation (2)

- **Access** to land and **land distribution** important in policy framework (Deininger & Byerlee, 2011)
- Agricultural **Total Factor Productivity** (TFP) growth in SSA countries has been relatively **slow** ~ 1% per year (Fuglie & Rada, 2013)
- Our study focuses on **Uganda, Tanzania, and Malawi**, 3 countries located in South East Africa with some shared borders and important natural resources (e.g., Lake Victoria, Lake Malawi) and some common features
- The **economy** of these 3 countries relies heavily on **agriculture**
- **80%** of **labor force** in **agriculture**, which is dominated by smallholdings



Motivation (3)

- Importance of agriculture means **access to land** a critical economic, environmental and socio-political issue, particularly given predominance of **small-scale holdings** (IFAD, UNP, 2013)
- Growth of large scale food distribution outlets might favor larger farms. Emergence of **Global value chains** has increased concerns on the future of small-scale farming (FAO, 2015)
- **Land grabbing →** concern regarding land policy and **threats** to existing farms and local communities (FAO, IIED, IFAD, 2009)
- Therefore, the relationship between **farm size and productivity**, has **regained importance**
- Inverse Relation Hypothesis or **IR-H**: farm size and productivity are inversely related, i.e., on average, small farms are more productive than larger farms. Thus, **land redistribution** could be **productivity increasing** (Barrett, Bellemare, & Hou, 2010)

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Motivation (4)

- The evidence supporting the **IR-H** has been **attributed** to:

- Imperfections in labor markets (Barrett, Bellemare & Hou, 2010; Henderson, 2015; Bardhan, 1973)
- Imperfections in credit markets (Lamb, 2003)
- Farmer heterogeneity (Assuncao & Braido, 2007)
- Land distribution *vis a vis* quality (Lamb, 2003; Kimhi, 2006; Ali & Deininger, 2015)
- Price uncertainty (Assuncao & Braido, 2007)
- Measurement errors (Carletto, Savastano & Zezza, 2013)

- **IR-H** typically examined using **output/land** (single factor productivity) as the dependent variable along with **OLS**
- Total Factor Productivity (**TFP**), **consistent** with long standing production function literature in agriculture and is superior than single factor productivity (Fuglie, 2010). Focusing only on **Yields can be misleading**

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Motivation (5)

- Another dimension of productivity that has received considerable attention in recent years is **Technical Efficiency** or TE (Bravo-Ureta et al., 2007; Fried, Lovell and Schmidt 2008 Bravo-Ureta et al., 2016)
- Main issue: How well do farmers perform compared to a **best practice production frontier**? The **distance** between observed and best practice output, given technology, inputs and the environment, provides a measure of TE (management)
- Studies focusing on both the **IR-H** and **TE** have been rare but we can see them growing

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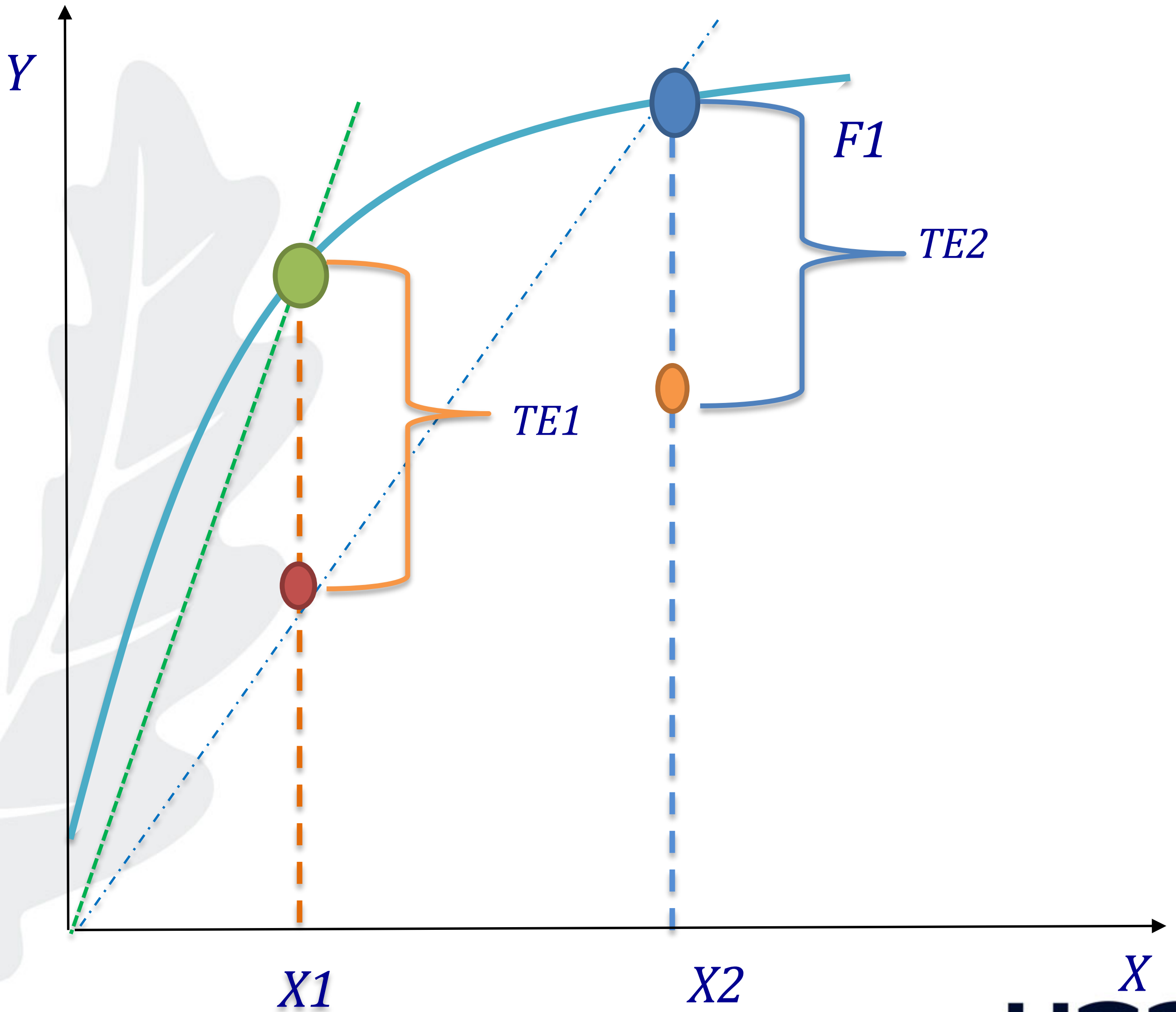
Motivation (6): Productivity vs. TE



Objectives

General Objective: to examine the IR-H in Malawi, Tanzania and Uganda

Specific Objectives Today:

1. **More comprehensive analysis,** in terms of model **specification**, of the IR-H than what has been the norm in the literature using stochastic production frontier (**SPF**) methodology
2. To examine **TFP** across **farm size class** and determine possible **productivity gains** that might associated with structural changes in farming
3. To investigate the **potential role of TE** as a way to improve productivity in the context of the IR-H

Contributions to the Literature

- Provide a **comparative analysis of the IR-H** across three countries that share important similarities including the predominance of **small holding farmers**

- To take advantage of the data available to provide a **richer model specification** to capture not only traditional inputs but also:
  - alternative measures of land
  - agro-ecological and environmental attributes
  - farm and farmer attributes
  - climatic variables

- To **account for unobserved heterogeneity** as a way to mitigate possible biases from omitted variables

- To provide a conceptually more robust approach to **measuring the IR-H by using TFP** instead of the typical single factor productivity approach along with TE measures

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IR-Hypothesis Literature (1)

- Several studies focus on **TFP in SSA** but **not** in connection with the **IR-H** (e.g., Block, 1994; Fuglie & Rada, 2013; Fuglie, 2010).

- The evidence shows that a number of factors have played a role on **TFP growth in SSA** including macroeconomic policies, R&D and crop expansion.

- Our focus is **farm level with a PRIMAL** approach: In theory **NO PRICES** are needed
- **Dual models** (cost functions/profit function). Prices are required.

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IR-Hypothesis Literature (2)

Authors/YR/Country	Method	Variables
Saini 1969/India	CD, OLS	Production/Land & Gross value of output crops: Conventional inputs
Bardhan 1973/India	CD, OLS	Value of crop production: Conventional inputs
Barrett, Bellemare, Hou 2010/Madagascar	CD, FE	Yield: Conventional inputs + (Soil quality measurements *(Carbon, Nitrogen, pH, Potassium, clay, silt, sand)*)
Assuncao, Braido 2007/India	CD, OLS	Total value of output: Conventional inputs + (Cropping Pattern, Main-Crop, Village, Year, Season)
Carletto, Savastano, Zezza 2013/Uganda	CD, OLS	Net agriculture revenue/Land & Maize yield: Conventional inputs + (Human Capital, Land Area SR and GPS, Self-reported Soil quality, Land flat, Land swamp/wetland, Plots Intercropped)
Sheng, Zhao, Nossal, Zhang 2014/Australia	CD &TL, OLS, First Diff, FE	Total Output/Land: Conventional inputs + (Region, Year, Industry)
Cohen 2015/Tanzania	OLS & IV	Revenue/Acre & Yield: Conventional inputs + (Land area SR and GPS, Soil type, Soil quality *(category)*, Steepness *(category)*, Fallowed recently, Intercropped, Irrigation, Loss *(birds, animals etc.)*

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IR-Hypothesis Literature (3)

Authors/YR/Country	Method	Variables
Lamb 2003/India	Panel FE& RE	Profits: Conventional inputs
Masterson 2007/Paraguay	Par. and Non-P	Production/Land: Conventional inputs + (Human capital, Technical assistance, Credit assistance, Marketing assistance)
Alvarez and Arias 2004/Spain	TL, Non-Par.	Milk production: Conventional inputs
Helfand, Levive 2004/Brazil	Panel, Non-Par TE	Gross Value Output: Conventional Inputs + (Market, Farmer Org, credit, soil conservation, irrigation)
Li , Feng, You, Fan 2013/China	SFA, TFP& TE	Value/Land & /Labor productivity &Profits???:Conventional inputs + (Human capital, Market participation, Credit)
Henderson 2015/Nicaragua	SFA, TL	Total Value Output/Land Operated & Farm Value-added/Land Operated & Labor/Land Operated: Conventional inputs
Ali, Deininger 2015/Rwanda	SF, CD&TL, TE	Total value of crop output: Conventional inputs + (Chemical fertilizer, Pesticide, Manure, Irrigated land)
Kagin, Taylor, Yúnez-Naude 2016/Mexico	Panel, SPF, FE, RE	Output value/Land: Conventional inputs + (Land slope, Human capital, Transaction costs, Access to US migration networks, Ethnicity)

Methodology (1)

As just indicated, Studies have typically regressed **Output/Land** using various specifications and OLS

– We use a **Cobb-Douglas** Stochastic Production Frontier (**SPF**) Model:

- The C-D functional form is used because it is **globally consistent** with a number of properties that come from economic theory (O'Donnell, 2012; 2014; 2016)
- SPFs estimated as **True Random Effects (TRE)** (Greene, 2005) to capture **unobserved heterogeneity** as well as **TE**
- Here we assume **heterogeneity** comes from unobserved **village level** effects

Methodology (2)

The **C-D TRE** model can be written as (Greene, 2005)

$$\ln Y_{it} = \alpha_i + \Sigma\, \beta_k \ln X_{kit} + \Sigma\, \delta_s W_{sit} + \Sigma\, \gamma_s F_{sit} + \Sigma\, \eta_s H_{sit} + \theta T + v_{it} - u_{it}$$

Y_{it} Value of agricultural production, i^{th} farm in period t

X_{kit} k^{th} input (land, expenses on purchased inputs, labor)
W_{sit} Weather variables (temperature and rainfall)
F_{sit} Farm attributes (several)
H_{it} Household characteristics (age, education, gender)
T Time dummies

α_i Village-specific random effect
v_{it} Symmetric error with a normal distribution
u_{it} One-sided component capturing TE (managerial ability) with an exponential distribution
$\beta, \gamma, \delta, \eta, \theta$ Parameters to be estimated

$TE = \exp(-u_{it})$ (Jondrow et al., 1982; Coelli et. al., 2005)

TFP for farm *i* in period *t* = Y_{it}/X where Y_{it} is as defined above and X is **aggregate input** (O'Donnell, 2016)

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Data (1)

- The data come from the **World Bank** (WB) Living Standards Measurement Studies-Integrated Surveys on Agriculture (**LSMS-ISA**)
- LSMS-ISA is a major **household survey** project funded by the Bill and Melinda Gates Foundation
- Implementation by the **World Bank** along with the respective **national statistical services**
- The **purpose** is to foster innovation and efficiency in statistical research focusing on the links between agriculture and poverty reduction in 8 selected African Countries
- Panel data are used: **2 rounds** for **Malawi** and **3** for **Uganda** and **Tanzania**

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Data (3) Variable Definitions

Variables	Definition
TVP	Total value of farm production (Real US Dollars)
Land	Farm size in hectares farmer reported and enumerator GPS measure
PIExp	Total expenses on purchased inputs (Real US Dollars)
Labor	Family and hired worker equivalent days used for all farm tasks (Men=1; Women=0.8; Children <14 years of age=0.5)
Temp	Degrees Celsius (C^o)
Precip	Precipitation in millimeters (mm)
CropS	Cropping system: Dummy variable equal to 1 if the cropping system is intercrop and 0 otherwise
Slope	Percent
Elevation	Meter above see level (m.a.s.l.)
EaseTill	Easy of tillage based on soil moisture. Dummy=1 if there is no constraint to the tiling and 0 otherwise (is a measure of soil tiling soil
NumPlot	Number of plots on the farm
DistRoad	Distance of the farm to the nearest road in meters
Age	Age head of household
Education	Years of education head of household
Gender	Dummy variable equal to 1 if head of household is male and 0 otherwise

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Data (2): Panel Dataset: LSMS-ISA

	Uganda		Tanzania		Malawi	
	Year(s)	Sample size (n)	Year(s)	Sample size	Year(s)	Sample size (n)
Round 1	2009/2010	2,607	2008/2009	3,280	2010/2011	12,271
Round 2	2010/2011	2,564	2010/2011	3,924	2013	4,000
Round 3	2011/2012	2,356	2012/2013	3,924		
Years between Rounds	1		2		3	
	Balanced Panel					
No. Farms/Year	711		1,066		1,374	
Total Observations	2,133		3,198		2,748	

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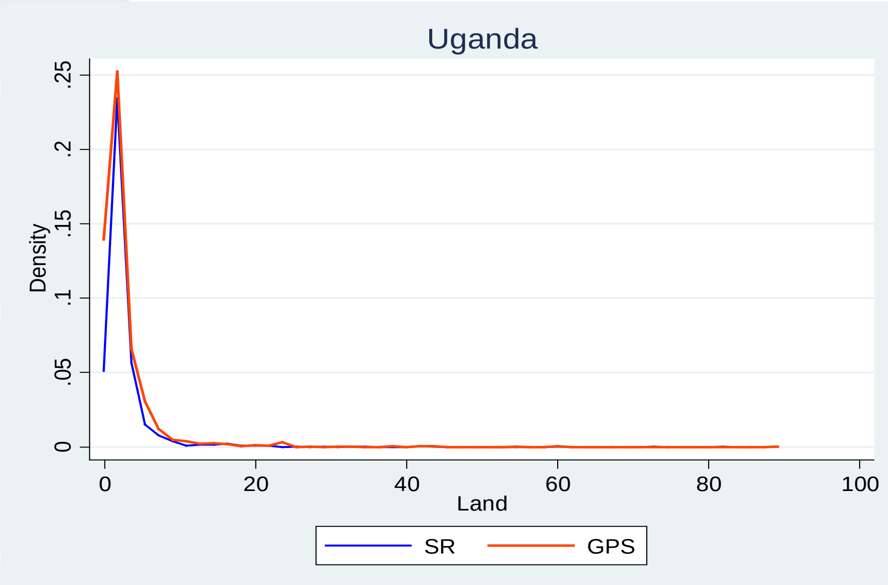
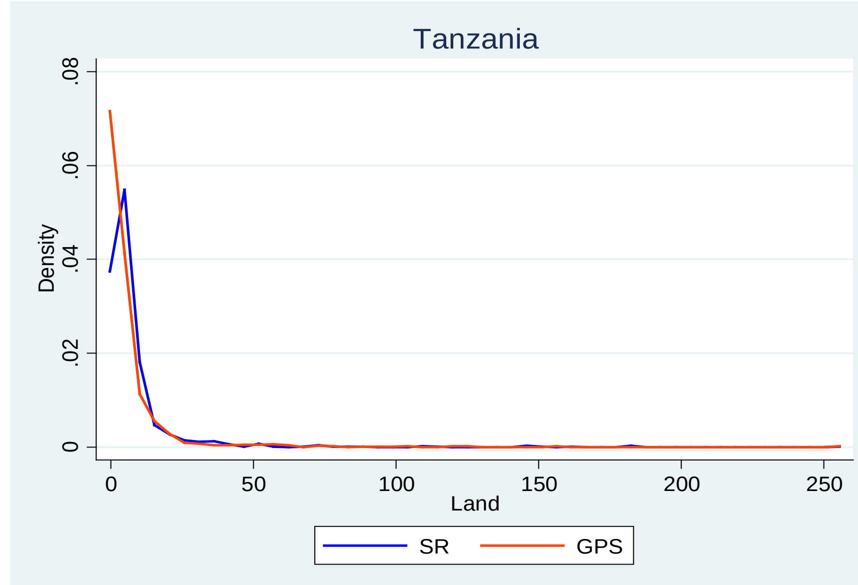
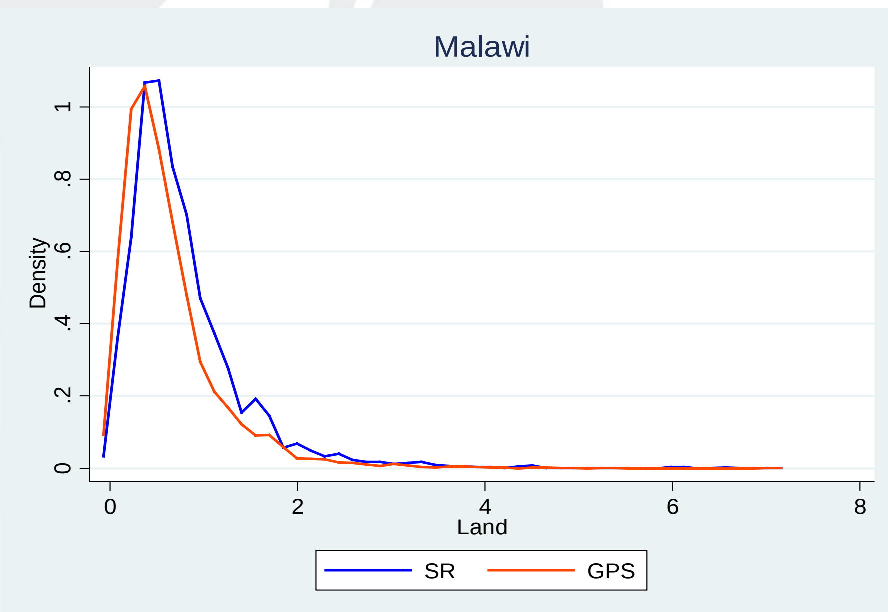
Data (4): Farm size Descrip. Stats. 1rst Round (Ha)

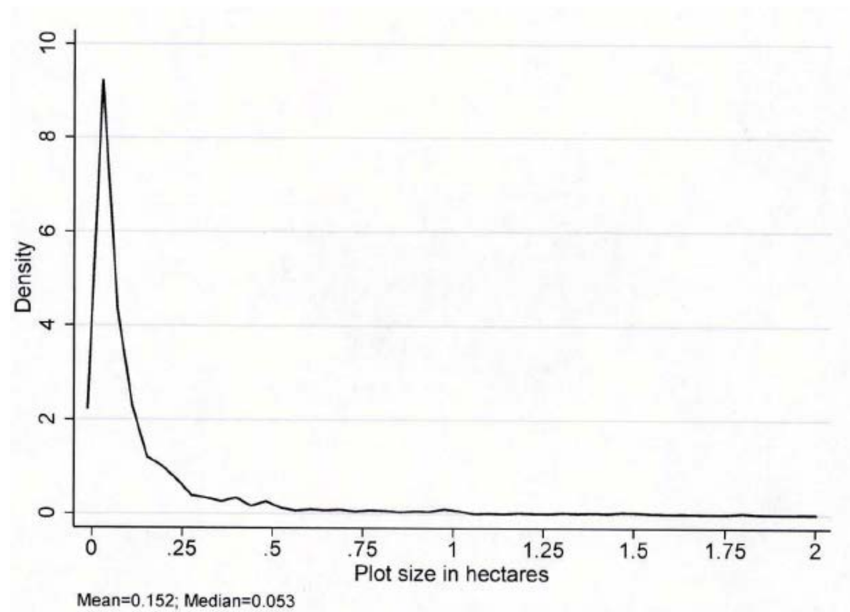
	Land	Number Obs.	Mean ha	Std. Dev.	Min ha	Max ha
Uganda	SR	2,310	2.37	6.77	0.020	89
	GPS	1,799	1.79	8.56	0.012	56
Tanzania	SR	2,032	2.98	8.69	0.040	253
	GPS	1,673	2.71	7.47	0.012	189
Malawi	SR	1,923	0.8	0.62	0.004	7.08
	GPS	1,846	0.75	8.11	0.004	8.08

Distribution of farm size









Data (5) Mean Difference Farm size GPS device vs. reported by farmers

Survey Round	Uganda		Tanzania		Malawi	
	Mean Difference GPS – Farmer	Mean test	Mean Difference GPS – Farmer	Mean test	Mean Difference GPS – Farmer	Mean test
1	-0.49 ***	Difference	0.62 **	Difference	-0.06 ***	Difference
2	-0.14 *	Difference	0.74	No Difference	-0.07 ***	Difference
3	-0.52 ***	Difference	-0.44 **	Difference		

** significant at 10%; ** significant at 5%; *** significant at 1%*

The **negative sign** indicates that **farmers** tend to **over estimate** farm size relative to GPS

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Results (1)

	Uganda		Tanzania		Malawi	
	SR	GPS	SR	GPS	SR	GPS
Land	0.29***	0.13***	0.42***	0.31***	0.45***	0.43***
PIExp	0.14***	0.13***	0.05***	0.05***	0.05***	0.05***
Labor	0.10***	0.16***	0.03***	0.03	0.08***	0.05**
Temp(C)	-3.27***	-3.23*	-0.09	-0.17	1.21**	0.70
Precipi (mm)	0.50**	0.65*	-0.01	-0.09	-0.34**	-0.23*
CropS	0.18**	0.28***	-0.08	-0.16	-0.004	-0.045
Slope (percent)	-0.18***	-0.11	-0.10***	0.04	-0.06*	-0.07**
Elevation (m)	0.66	0.15	0.13***	0.27***	0.61***	0.50***
Ease_Till	0.11	0.14	0.12	0.76	-0.06	-0.09*
No. of Plots	0.18***	0.21**	0.11***	0.17*	0.51***	0.59***
Dist. to road	0.05**	0.09***	0.03**	-0.05	-0.02*	-0.02**
Age	-0.29**	-0.25	-0.0524	-0.29	0.17**	0.15**
Education	-0.002	-0.01	0.05***	0.04*	0.01**	0.01**
Gender	-0.16	-0.38***	0.006	0.07	0.17***	0.15***
T2	0.41***	0.39***	-0.08	-0.03	-1.11***	-1.09***
T3	0.92***	0.72***	-1.04***	-0.96***		
Intercept	8.21	10.09	5.67***	6.47***	-0.101	1.743
N	2,133	1,119	3,198	588	2,748	2,620
Function. Coeff.	0.53	0.42	0.50	0.39	0.57	0.53

* *significant at 10%; ** significant at 5%; *** significant at 1%*

Results (2)

- **Output** is **inelastic** with respect to the **function coefficient** i.e., sharply decreasing RTS ranging from 0.39 (TZ GPS) to 0.57 (Malawi Self-reported)
- **Negative** effect of **Temperature** except for Malawi where it is positive and significant
- **Positive** effect of **Precipitation** on TVP for Uganda but not for Malawi, and not significant for Tanzania
- **Negative** effect of **slope** of the farm on TVP
- In all three countries number of **plots** has a **positive** effect on TVP, particularly in Malawi

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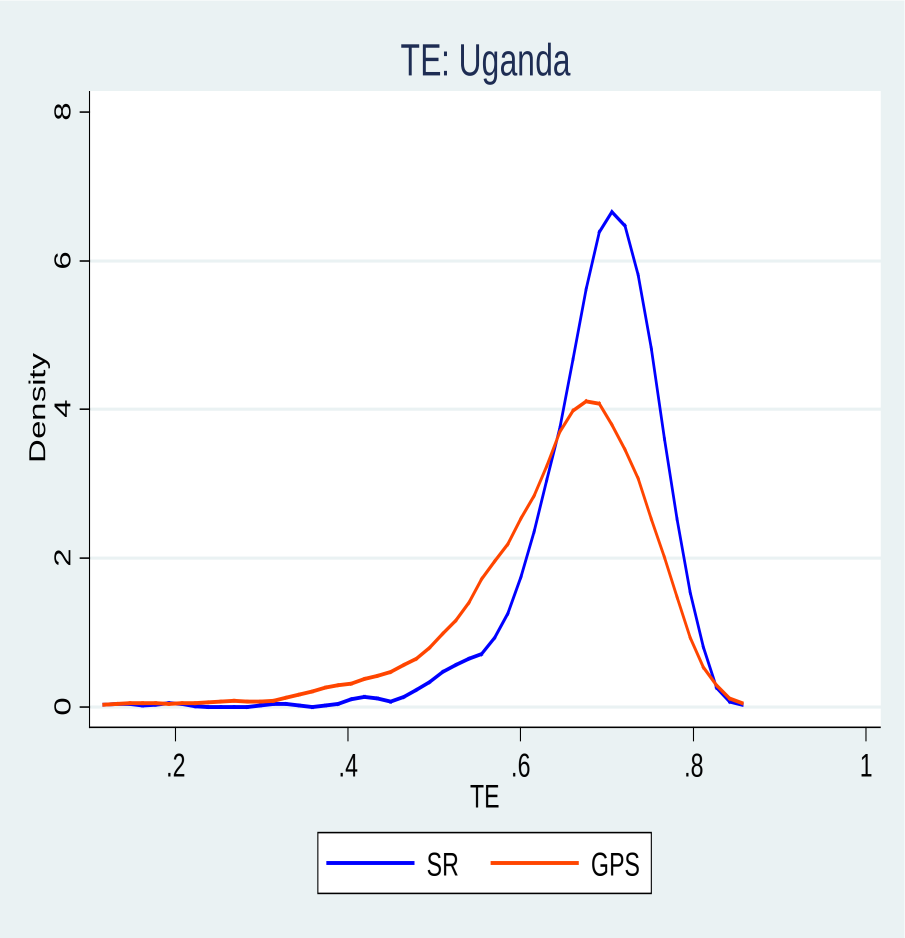
Results (3): Technical Efficiency, Uganda

Class	2009		2010		2011	
	SR	GPS	SR	GPS	SR	GPS
1	0.67	0.59	0.69	0.64	0.68	0.64
2	0.68	0.60	0.68	0.60	0.67	0.60
3	0.67	0.61	0.68	0.61	0.68	0.59
4	0.68	0.61	0.70	0.61	0.68	0.60
5	0.69	0.61	0.68	0.61	0.68	0.62
Overall	*0.68*	*0.60*	*0.68*	*0.61*	*0.68*	*0.61*



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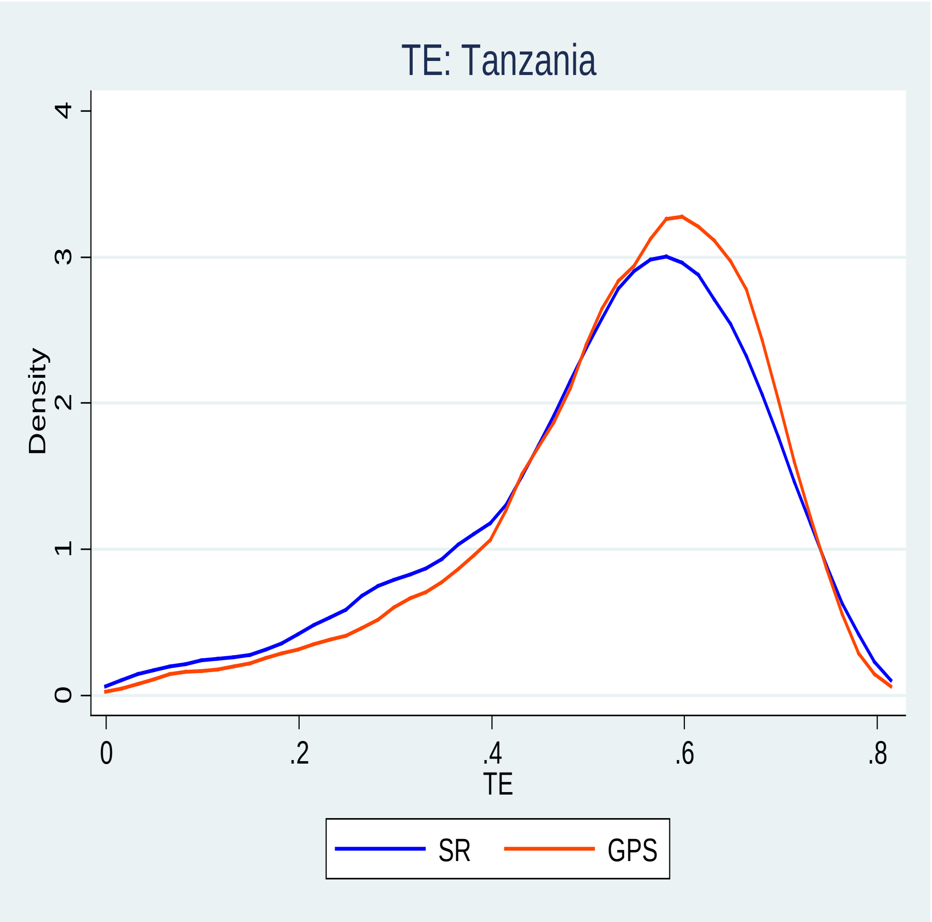
Results (4): Technical Efficiency, Tanzania

Class	2008		2010		2012	
	SR	GPS	SR	GPS	SR	GPS
1	0.55	0.61	0.52	0.53	0.50	0.54
2	0.53	0.56	0.50	0.58	0.53	0.55
3	0.53	0.54	0.52	0.50	0.54	0.55
4	0.48	0.55	0.51	0.57	0.56	0.60
5	0.49	0.52	0.50	0.55	0.55	0.58
Overall	*0.51*	*0.55*	*0.52*	*0.55*	*0.52*	*0.56*



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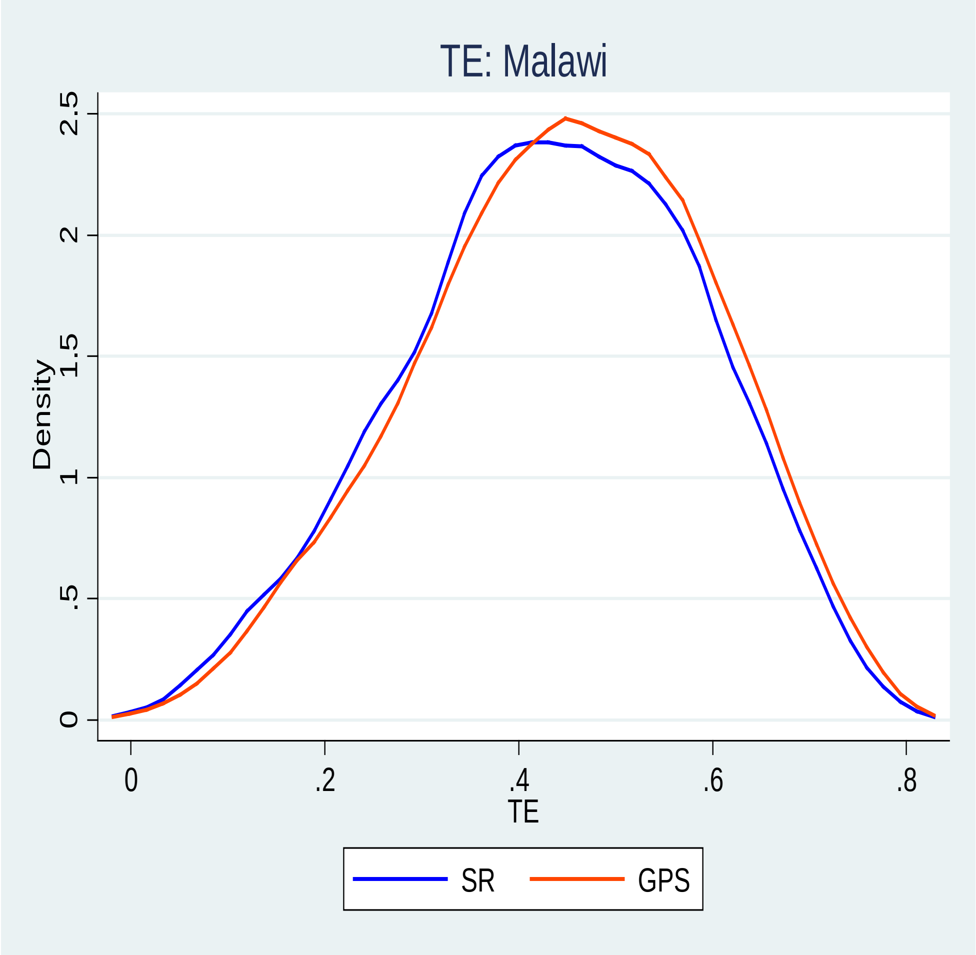
Results (5): Technical Efficiency, Malawi

Class	2010		2013	
	SR	GPS	SR	GPS
1	0.42	0.42	0.46	0.47
2	0.42	0.45	0.42	0.44
3	0.42	0.42	0.41	0.43
4	0.45	0.44	0.42	0.42
5	0.45	0.46	0.45	0.45
Overall	*0.43*	*0.44*	*0.43*	*0.44*



Results (5): Technical Efficiency

- Average **TE** is **similar** across **models** and **farm size** classes for all three countries
- However, **Uganda** presents the **highest** level of **TE**, while **Malawi** presents the **lowest**
- **Lowest** average **TE** is for Malawi, this is **consistent** with a couple studies for this country (Holden and O'Donnell, 2015; Tchale, 2009)
- **TE** measures are, overall, **consistent** with the estimates reported in the meta-analyses by Bravo-Ureta et al. (2007) and (2016)
- **Farms** tend to **underperform** across the study area

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Results (6) Uganda: TFP by class ($US/agg. Input)

	2009		2010		2011	
Farm Size Class	SR	GPS	SR	GPS	SR	GPS
1	214	52	181	42	630	130
2	145	32	313	26	313	67
3	187	35	268	33	268	41
4	130	42	153	35	335	110
5	84	22	77	19	228	37

TFP: consistently inversely related with Farm Size Class lending **support to the IR-H**

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Results (7) Tanzania: TFP by class ($US/agg. Input)

	2008		2010		2012	
Farm Size Class	SR	GPS	SR	GPS	SR	GPS
1	248	532	226	473	114	191
2	165	249	181	280	86	111
3	147	122	151	150	75	75
4	104	75	135	199	69	77
5	95	68	111	109	52	89

Again TFP consistently inversely related with Farm Size Class lending **support to the IR-H**. One exception.

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Results (8) Malawi: TFP by class ($US/agg. Input)

	2010		2013	
Farm Size Class	SR	GPS	SR	GPS
1	279	274	131	137
2	252	358	93	124
3	265	359	78	149
4	359	436	90	123
5	333	492	107	171

Evidence concerning **TFP and Farm Size is mixed**. This might be consistent with the fact that farms in Malawi are very small

Conclusions (1)

- Self-reported compared to GPS **land measures**: findings generally consistent, not identical. The **IR-H** holds with both measures for **Uganda and Tanzania**
- **Malawi** shows mixed results concerning the IR-H
- **Function coefficient consistently low** which suggest plenty of room to increase productivity. But, why are these numbers so low?
- **TE** averages are also low indicating lots of **room** to improve **managerial performance**
- **TFP** according to five farm size classes shows that the **smallest farms** have the **highest** average TFP for **Uganda and Tanzania** consistent with the IR-H

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Conclusions (2)

- Family farms are usually **subdivided** from one **generation** to the next. How long can this go on for?
- **Implications** as agriculture becomes increasingly **globalized**?
- **Dürr (2016) on Guatemala**: "Smallholder value chains include mainly informal sectors and create more jobs than commercial agriculture. … a reorientation of agricultural and land policies toward small-scale food producers and within a comprehensive policy of integrated rural development is not only necessary in terms of social equity but also for boosting economic development".

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Additional Work

- Improvements as we move to finish this part of the project:
  - **Robustness**
  - Compare TRE with TFE at **village level**
  - Consider TFE and TRE at the **farm level** and this would require dealing with Incidental Parameters issue (T=2 or 3) following Belotti et al. (2013)
  - Different **data configurations**: Unbalanced panels; cross sectional estimates

– **TFP growth rates** over time and farm size

– **TFP decomposition** (Tech. Change; TE change; Input effect)

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Thank You!!