

# Rising Tractor Use in sub-Saharan Africa: Evidence from Tanzania

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- The drivers of rising use of mechanization services on smallholder farms remain poorly understood

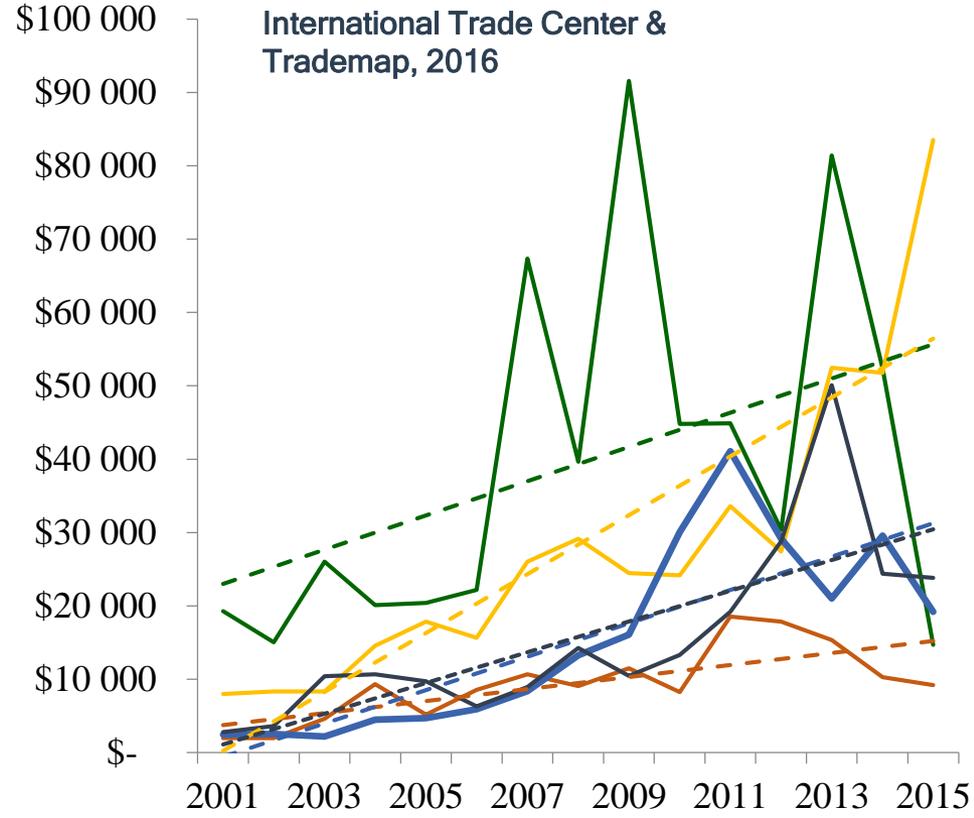
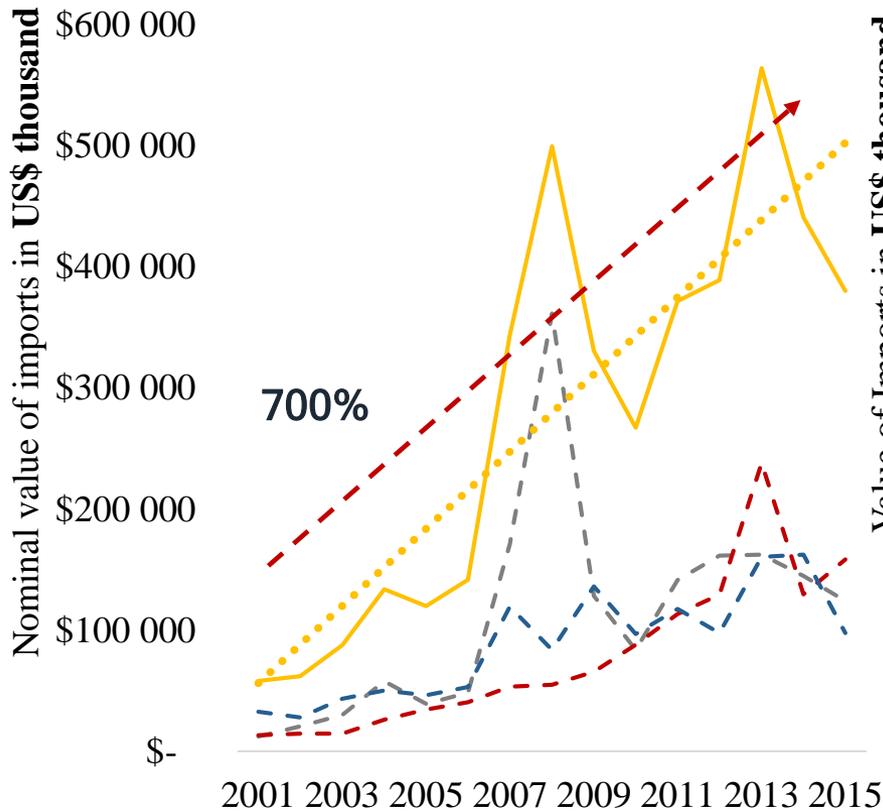
## Objectives:

- To identify the factors driving recent rise of mechanization use by small-holder farmers in Tanzania
- To explore the potential role of medium & large-scale farms in promoting a movement to more capital-intensive forms of farming, not only on larger farms but on smallholder farms as well
- To evaluate whether evolving trends in factor use between labor and capital on smallholder farms in Tanzania is consistent with the Hayami-Ruttan Induced Innovation theory

# Import Data shows an Increase in Tractor Demand



Nominal value of tractor imports into region is increasing



- Sub-Saharan Africa
- - - Southern Africa
- - - North Eastern Africa
- - - Western Africa

- Ghana
- Kenya
- Zambia
- - - Linear (Nigeria)
- - - Linear (Tanzania)

- Nigeria
- Tanzania
- - - Linear (Ghana)
- - - Linear (Kenya)
- - - Linear (Zambia)

# Conceptual Framework

## Causes of Rising Tractor Use in SSA



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# Causes of Increased Tractor Use



Conceptual Framework: Hayami & Ruttan Induced Innovation

## Supply:

- Cost of capital has declined in Africa since 2000, real interest rates lower & penetration of banking into rural areas has improved ([Andrianaivo and Yartey, 2009](#); [Ojah and Odongo Kodongo, 2015](#))
- Many medium-scale farmers own/use tractors. As these farmers expand, there is a growing presence of tractors in rural areas

## Demand:

- Rising opportunity cost of farm labor, especially in areas experiencing economic dynamism ([Tschirley et al., 2015](#); [Yeboah and Jayne, 2018](#))
- Shifts in labor force into more diversified, off-farm activities associated with economic transformation ([Yeboah & Jayne, 2018](#))
- Higher global food prices → Incentives to expand area under cultivation → Technologies to facilitate area expansion ([AGRA, 2016](#); [Jayne et al., 2016](#); [Richards et al., 2016](#); [UN Population prospects, 2017](#))

# Data & Methods



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- Tractor importation data for 40 African countries - Trademap
- Tanzanian National Panel Survey (NPS) for 2008/09, 2010/11, 2012/13 & 2014/15 (TNBS & World Bank) - 9,726 observations for pooled data & 1,672 for HH-level panel
- Demand function for **tractor rental services**:

1) Pooled generalized linear model (GLM) probit which provides a flexible generalization of ordinary linear regression

2) Mundlak-Chamberlain device (Mundlak 1978; Chamberlain 1984), providing an estimator that Woolridge (2010) refers to as the Correlated Random Effects (CRE) model which address the issue of unobserved heterogeneity at household level

- Ordinary Least Squares (OLS) multiple regression to test induced innovation hypothesis

where  $Y$  = % change in the number of HH using tractors:  $\Delta$  2008-2010;  $\Delta$  2010-2012  $\Delta$  2012-2014 & key variable of interest:  $\Delta$  in factor price (FP) ratio:  $\Delta$  2008-2010;  $\Delta$  2010-2012  $\Delta$  2012-2014 where FP ratio = wage rate divided by tractor rental cost



$$P(Y_{tractor_{rent}} = 1 \mid X_k) = f(X, C, R, Y) + \epsilon_i$$

$X$  = household characteristics

$C$  = community characteristics

$R$  = region conditions

$Y$  = year dummy variables

for panel estimation  $\epsilon_{it} = \alpha_i + \mu_{it}$

- $X$ : household land cultivated, gender & age of household head, asset wealth & market access conditions
- $C$ : local wage rates, fertilizer prices, tractor rental rates, *share of MS farms as % of total number of farms in district*
- $R$ : to regional dummy variables (30 regions)
- $Y$ : survey year dummies (3 for pooled sample; 2 for household panel analysis)

# Results: Descriptive Statistics

- Changing tractor use in Tanzania
- Shift in rental markets, especially among small-scale producers
- Tractor rental use is concentrated in certain regions



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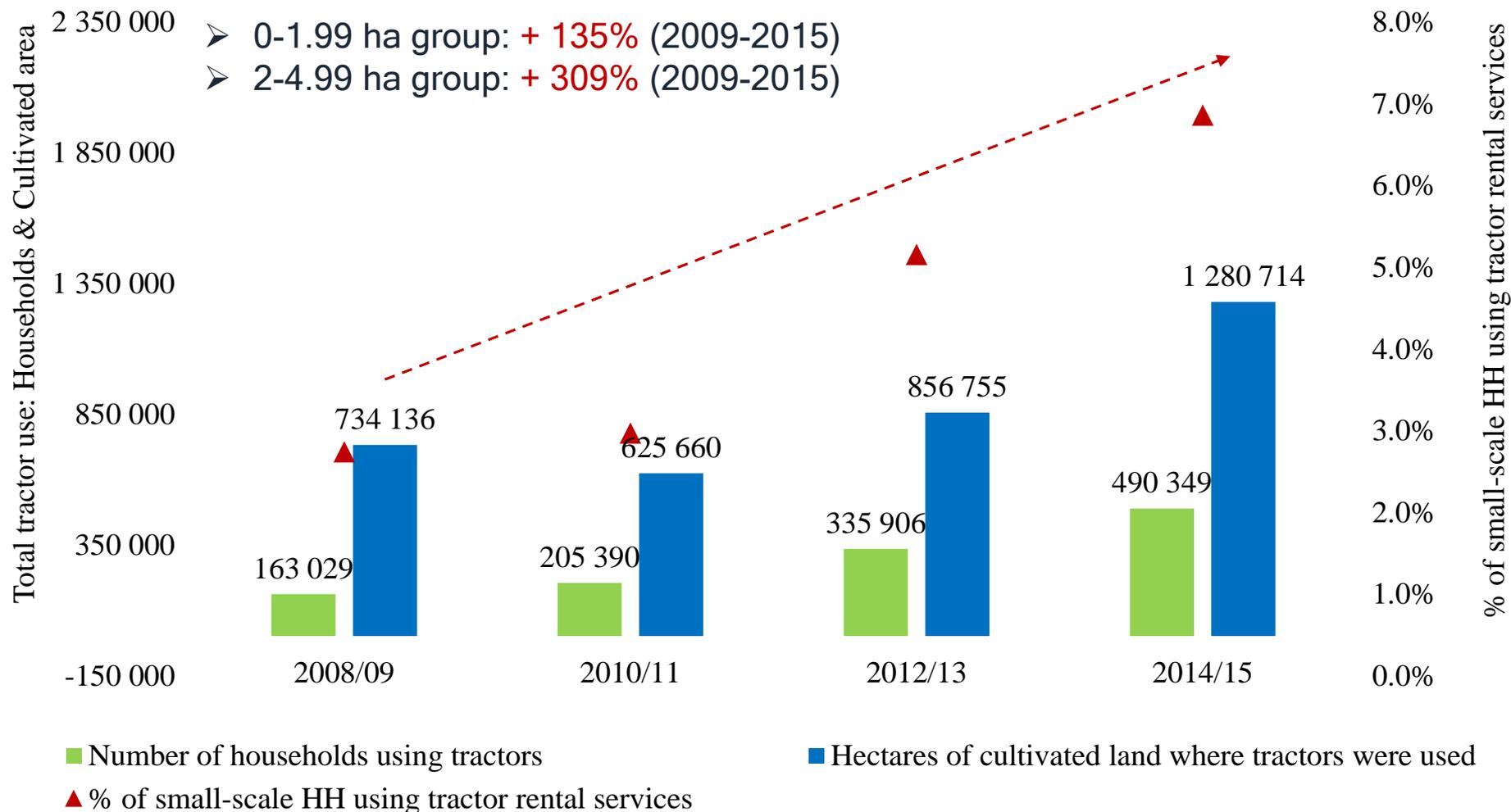
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# Changing Tractor Use in Tanzania

More households & area using tractors; small-scale farms increasingly using rental services



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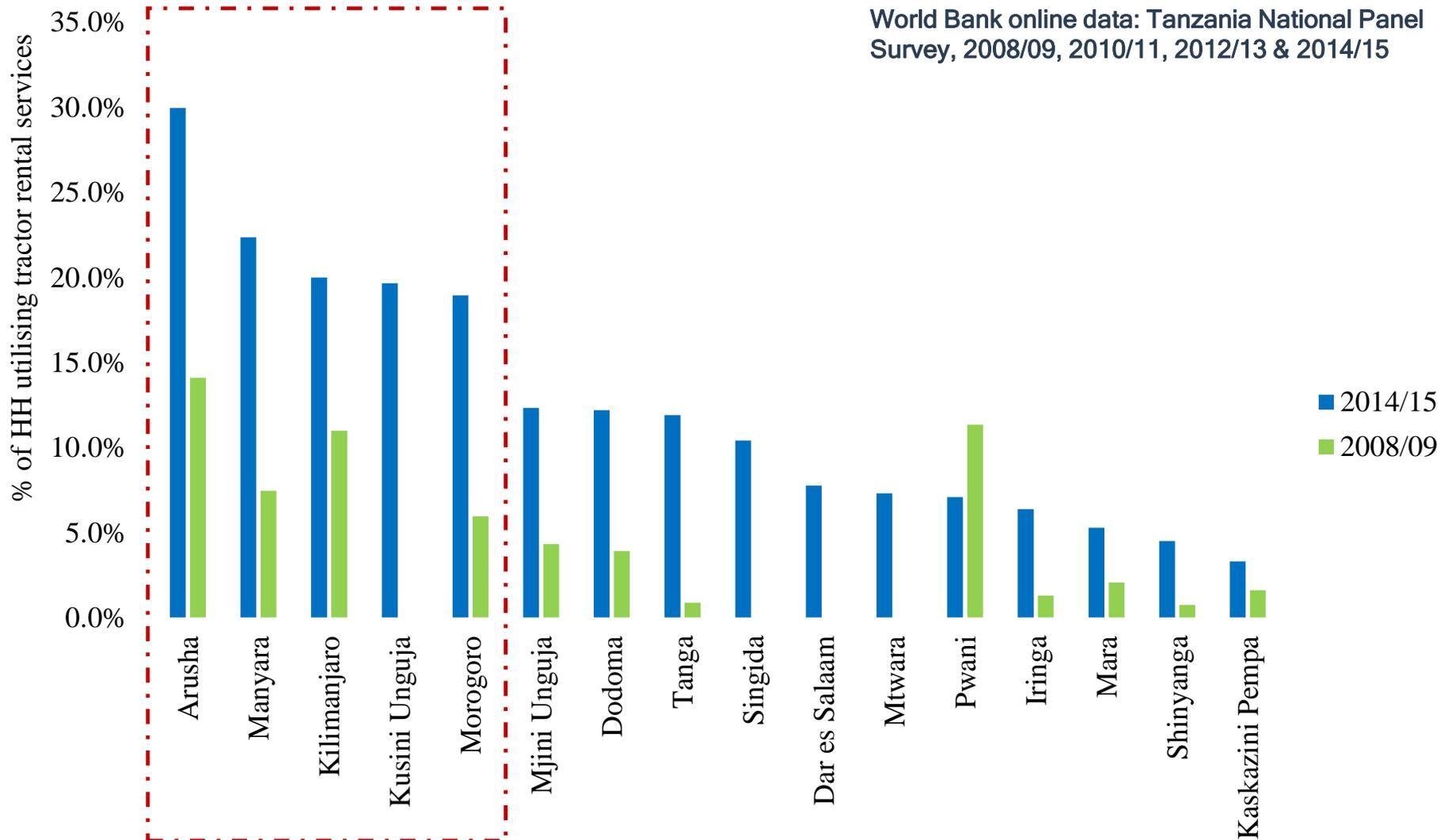


World Bank online data: Tanzania National Panel  
Survey, 2008/09, 2010/11, 2012/13 & 2014/15



# Tractor rental use is concentrated in certain regions

Some regions have experienced higher growth since 2008/09



# Estimation Results

- Pooled GLM probit
- Mundlak-Chamberlain (MC) indicator / CRE model
- Predicted Probabilities



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# Pooled GLM & MC-CRE Probit Results

Selective output for 4 approaches

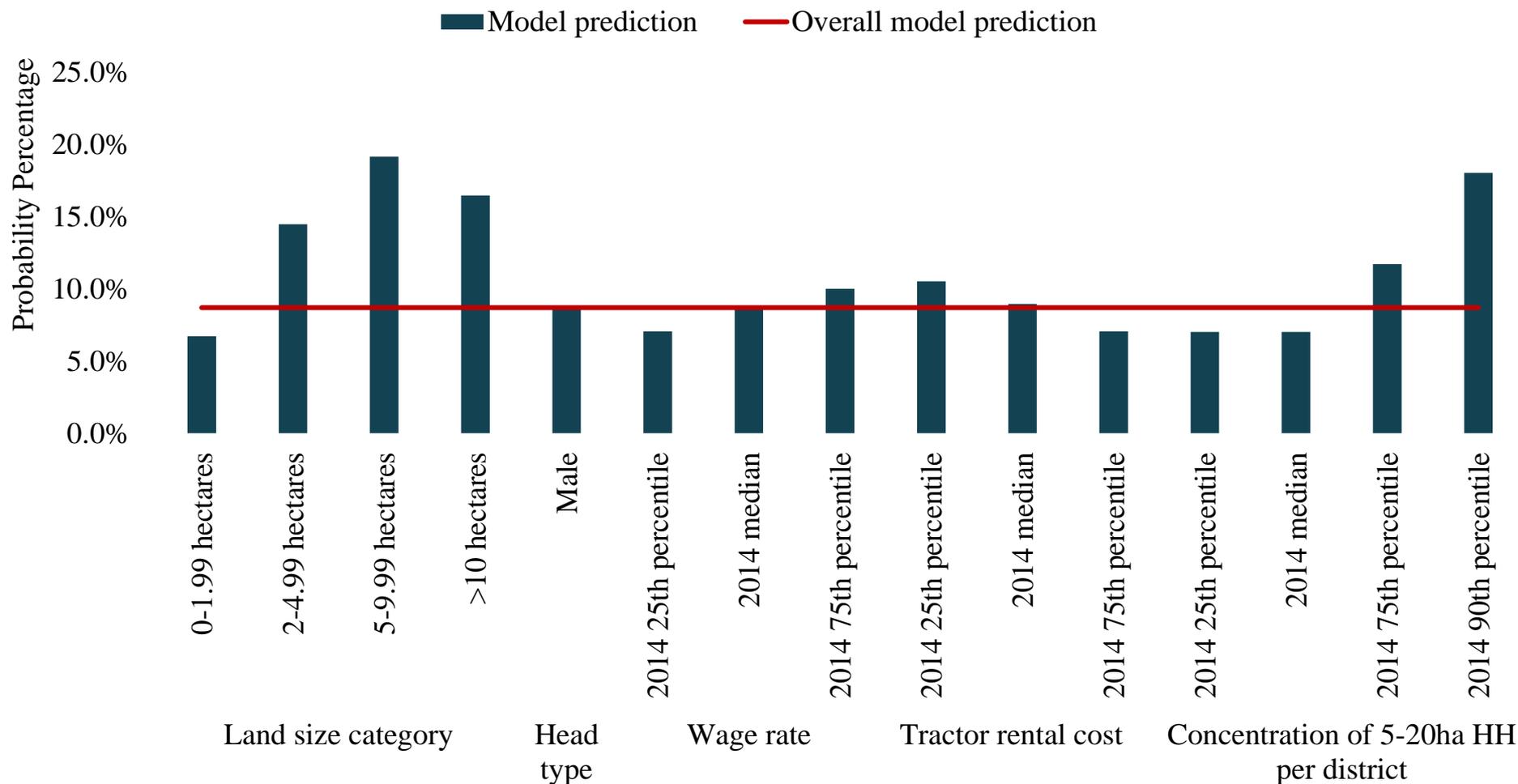


Estimation approach	Pooled GLM Probits		Mundlak-Chamberlain Correlated Random Effects	
	2% rental regions	2% rental regions	2% tractor rental regions	2% tractor rental regions
Dataset		Limited to HH located in 0-5 ha		Limited to HH located in 0-5 ha
Cultivated Land Size Distribution = 2 - 4.99 hectares	0.44***	0.46***	0.33*	0.33*
Cultivated Land Size Distribution = 5 - 9.99 hectares	0.62***	.	0.41	.
year = 2012/13	0.31***	0.36***	0.50***	0.52***
year = 2014/15	0.59***	0.64***	.	.
Household head sex: Male	0.24***	0.26***	0.18	0.26
log_market_dist	0.01	-0.01	-0.20*	-0.18
log_wage_rate_LP	0.19***	0.19***	0.21***	0.19***
log_trac_rent_cost	-0.22***	-0.31***	-0.30**	-0.31*
hh_5_10_ha	4.37***	4.14***	0.63	0.35
Region = Arusha	0.76***	0.79***	0.95*	1.23**
Region = Kilimanjaro	0.95***	0.96***	1.00**	1.27**
Region = Morogoro	0.59***	0.74***	1.44***	1.72***
Region = Pwani	0.77***	0.79***	1.57*	1.77**
Region = Manyara	0.91***	1.00***	1.67**	1.85***
log_maize_price_mean	.	.	0.70***	0.63***
log_trac_rent_cost_mean	.	.	-0.80**	-0.83*
hh_5_10_ha_mean	.	.	8.90*	12.21***
Constant	-3.32***	-2.47**	-0.03	0.02
Observations	3,728	3,524	1,644	1,564

pval in parentheses  
\*\*\* p<0.01, \*\* p<0.05, \* p<0.1

# Predicted Probability Scenarios

Despite overall low success rate, results change quite substantially as we control for certain variables

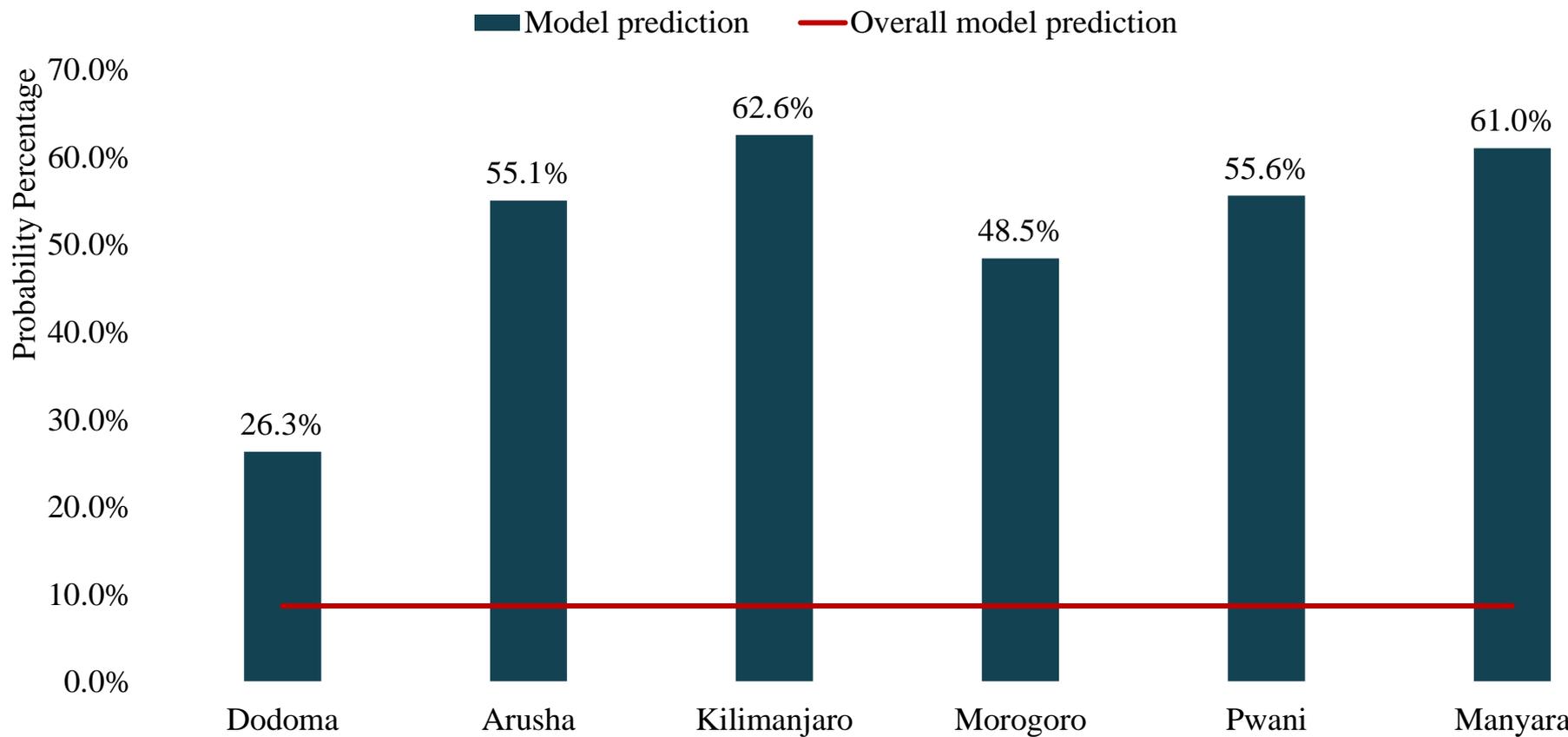


World Bank online data: Tanzania National Panel Survey, 2008/09, 2010/11, 2012/13 & 2014/15

# Tractor adoption - Regionally concentrated within specific groups



Predicted probabilities for land size group = 5-9.99; year = 2014, head type = male & concentration of medium-scale producers per district = 2014 median



Predicted probabilities for regions where land size = 4-9.99 ; year =2014 ; head type = male & concentration of 0-5 ha producers = 2014 median

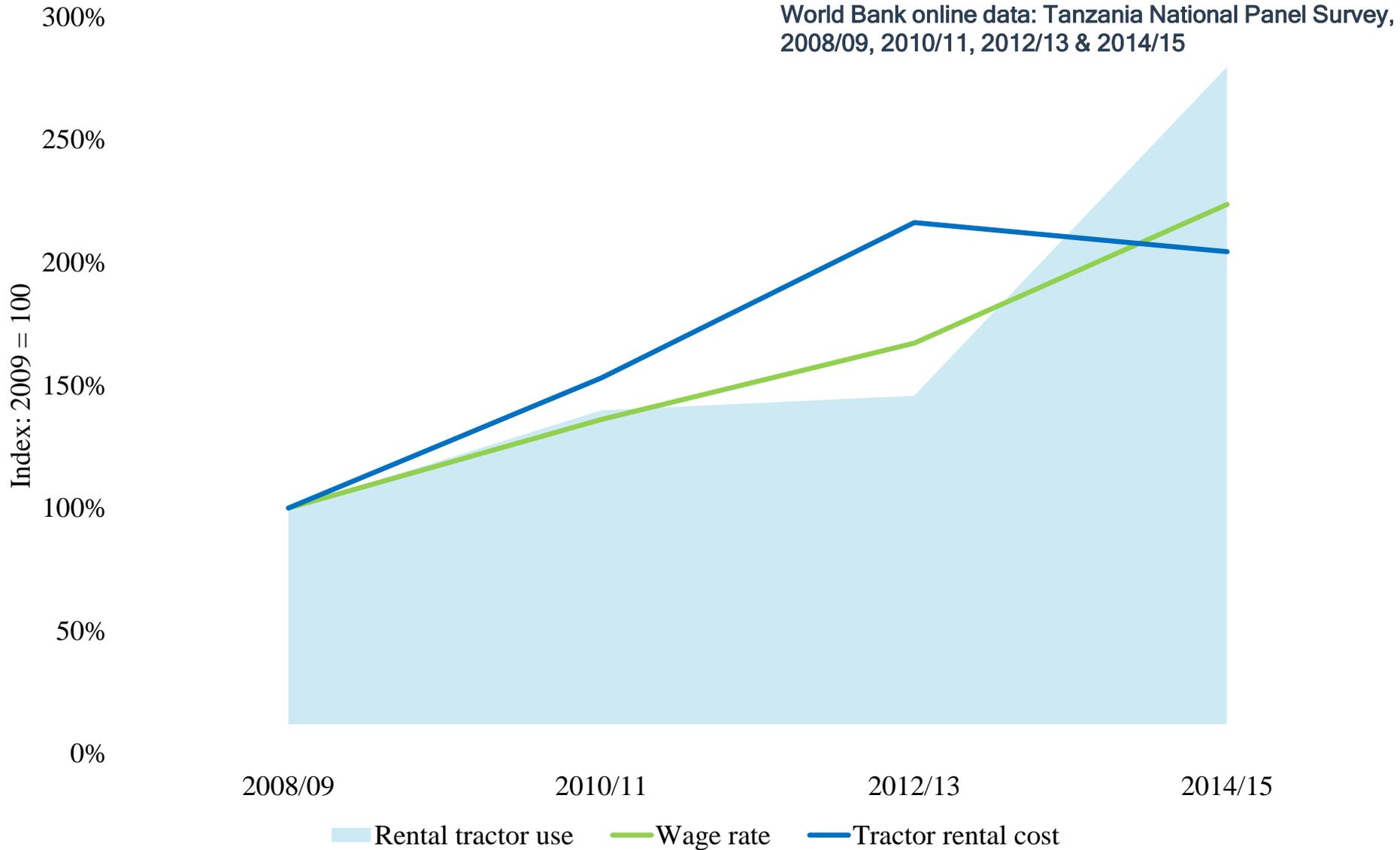
World Bank online data: Tanzania National Panel Survey, 2008/09, 2010/11, 2012/13 & 2014/15

# Induced Innovation Hypothesis

Mean of median changes in district-level factor prices



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# Induced Innovation Hypothesis



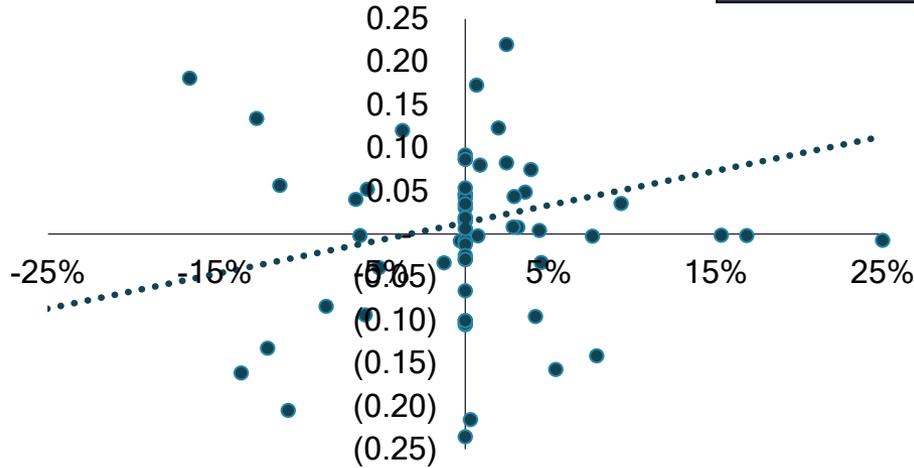
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Relative change in factor prices vs. change in share of farms renting tractors

Change: FP 2008-2010

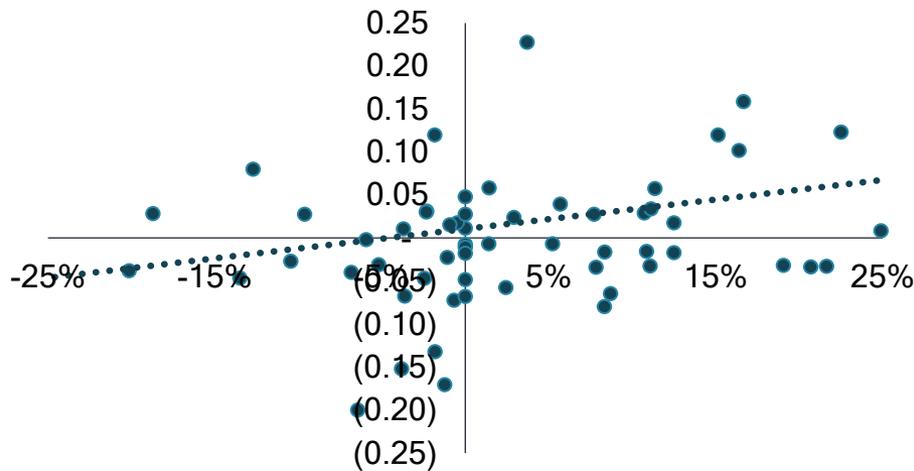
Y axis: Change in factor price ratio



Change: FP 2010 - 2012

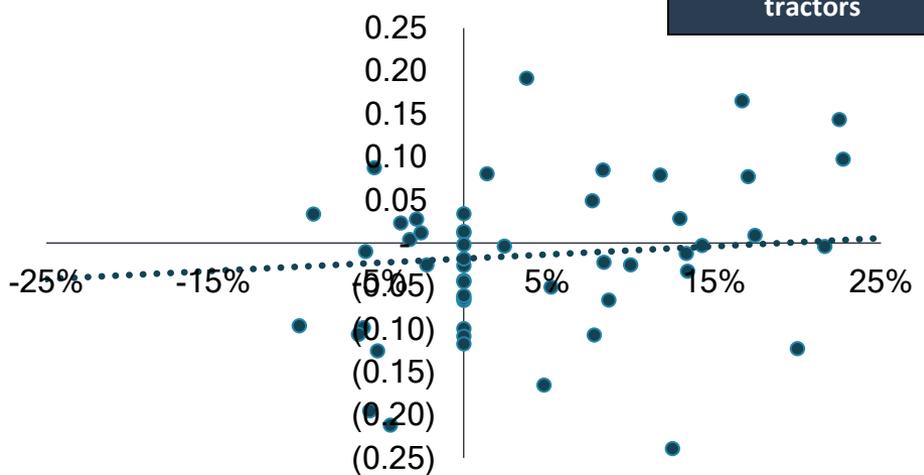


Change: FP 2012-2014



Change: FP 2008-2014

X axis: % change in  
# of farms renting  
tractors



# Induced Innovation Hypothesis Testing

Relative change in factor prices vs. change in share of farms renting tractors



## Model Specification to test the induced innovation hypothesis:

$Y$  = % change in the number of HH renting tractors:  $\Delta$  2008-2010;  $\Delta$  2010-2012  $\Delta$  2012-2014

$X_1$  =  $\Delta$  in factor price (FP) ratio:  $\Delta$  2008-2010;  $\Delta$  2010-2012  $\Delta$  2012-2014 where FP ratio = wage rate divided by tractor rental cost

$X_2$  = Household asset wealth (lagged)

$X_3$  = Market distance from household to closest market (lagged)

$X_4$  = Quantity maize harvested in kilograms per hectare (lagged)

$X_5$  = Maize price in TZS per kilogram sold (lagged)

$X_6$  = Fertilizer cost in TZS per kilogram of fertilizer (lagged)

$X_7$  = Concentration of 5-10 hectares farming households per district (lagged)

# Induced Innovation Hypothesis Testing

Relative change in factor prices vs. change in share of farms renting tractors



**OLS Regression Statistics for Change: % change in the number of HH renting tractors: Δ 2008-2010; Δ 2010-2012 Δ 2012-2014**

				<u>Unrestricted Model</u>	
F-test	2.620	Prob(F)	0.012	F-test	2.620
MSE <sup>1/2</sup>	0.080	CV Regr	560.623	R <sup>2</sup>	0.050
R <sup>2</sup>	0.050	Durbin-Watson	2.065	RBar <sup>2</sup>	0.031
RBar <sup>2</sup>	0.031	Rho	-0.036	Akaike Information Criterion	-5.034
Akaike Information Criterion	-5.034	Goldfeld-Quandt	0.354	Schwarz Information Criterion	-4.958
Schwarz Information Criterion	-4.958				

95%	Intercept	Change in Factor Price Ratio	Lag_asset_w ealth	Lag_market_ dist	Lag_qty_ har vested	Lag_maize_ p rice	Lag_fert_ cos t	Lag_hh_5_10 _ha
Beta	0.00	0.08	0.00	0.00	0.00	0.00	0.00	0.10
S.E.	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.12
t-test	-0.32	2.98	0.29	-0.97	2.56	1.02	0.50	0.88
Prob(t)	0.75	0.00***	0.77	0.33	0.01***	0.31	0.61	0.38
Elasticity at Mean		-0.026	0.023	-0.348	0.547	0.685	0.270	0.186
Partial Correlation		0.157	0.015	-0.052	0.136	0.056	0.025	0.047

- OLS regression indicates significant & positive signs for the change in factor price ratio & quantity of maize harvested on the % change in the number of HH renting tractors

# Conclusions



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- Concentration of medium-scale farms per district coupled with increased tractor rental use by smallholders
- Landholding size coupled with increased tractor rental use
- Increase in # of households using tractors not limited to larger-scale producers
- Largest increase in tractor rental use was observed in the 2-4.99 and 5-9.99 hectares' land size groups
- Significant regional variation in tractor rental use & adoption
- Estimation results uphold the importance of relative changes in factor prices consistent with the induced innovation hypothesis
- Although overall tractor rentals remain low, it is rising particularly in rural areas experiencing economic transformation

# THANK YOU



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# Supporting Slides



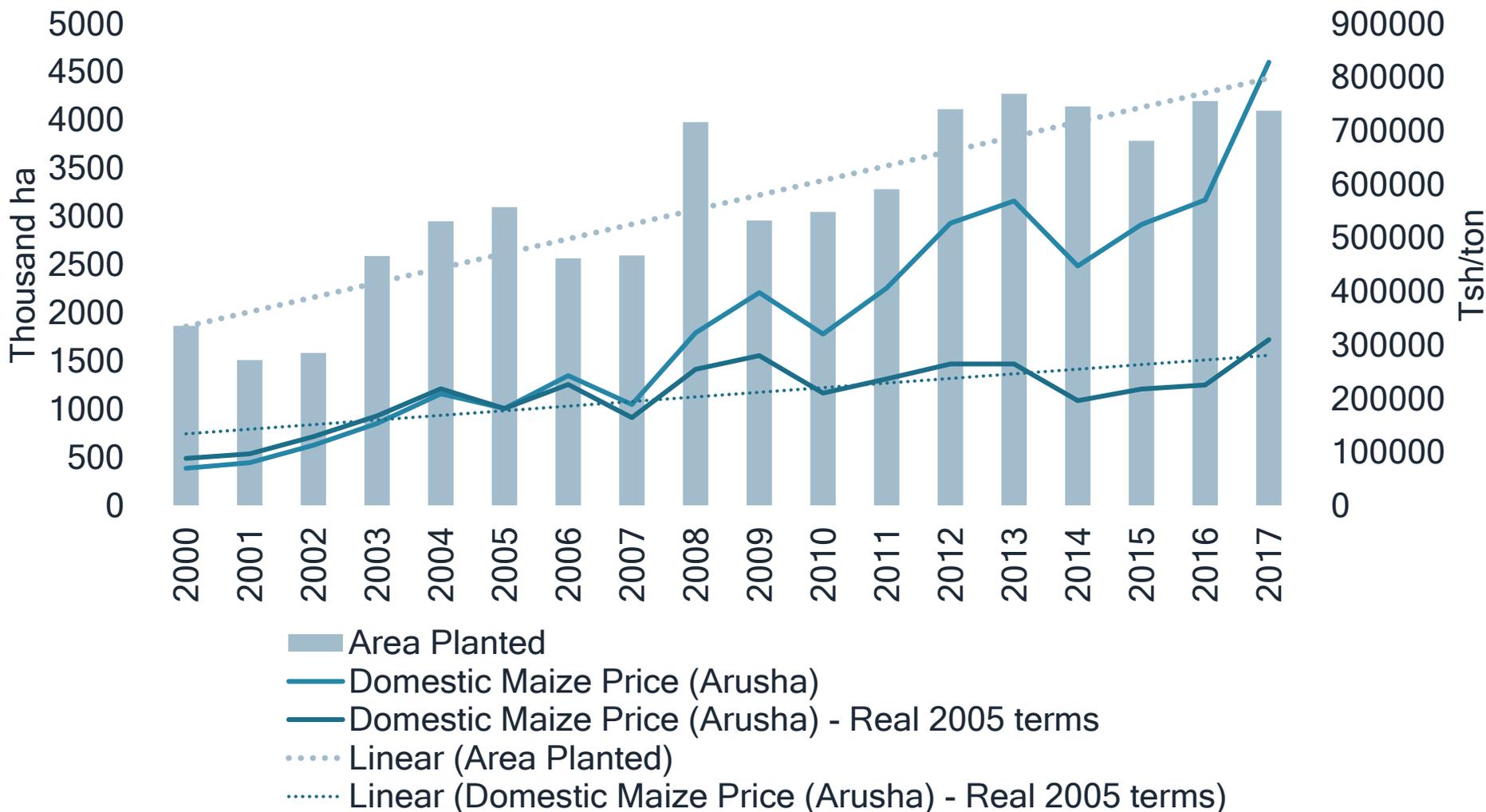
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# Tanzania Maize Market

## Area increase & increase in real maize prices

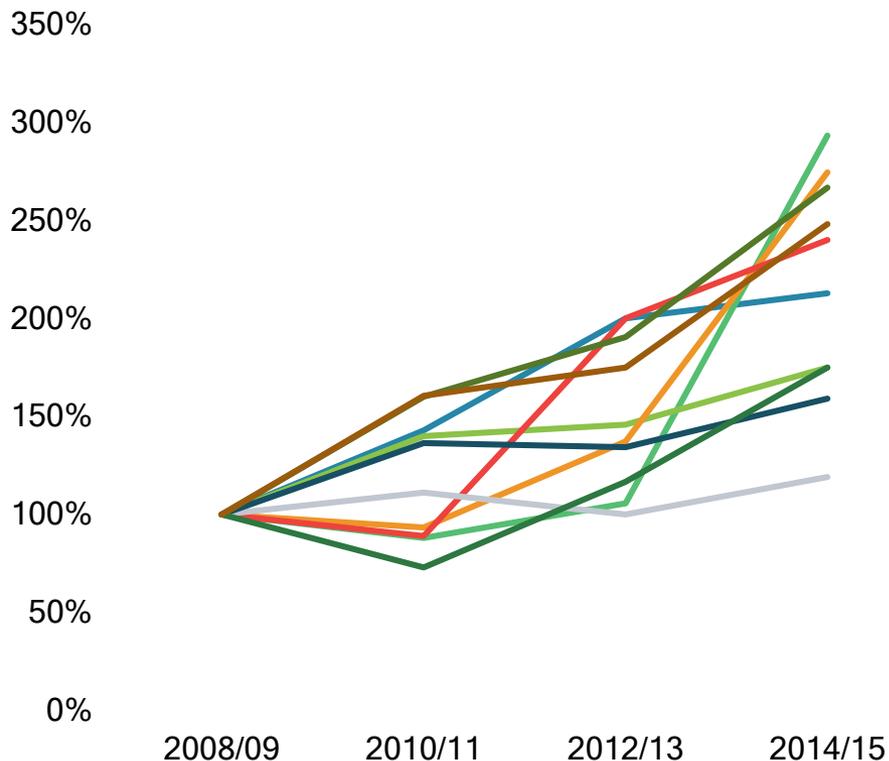


# Induced Innovation Hypothesis

Change in wage rate vs. tractor rental costs



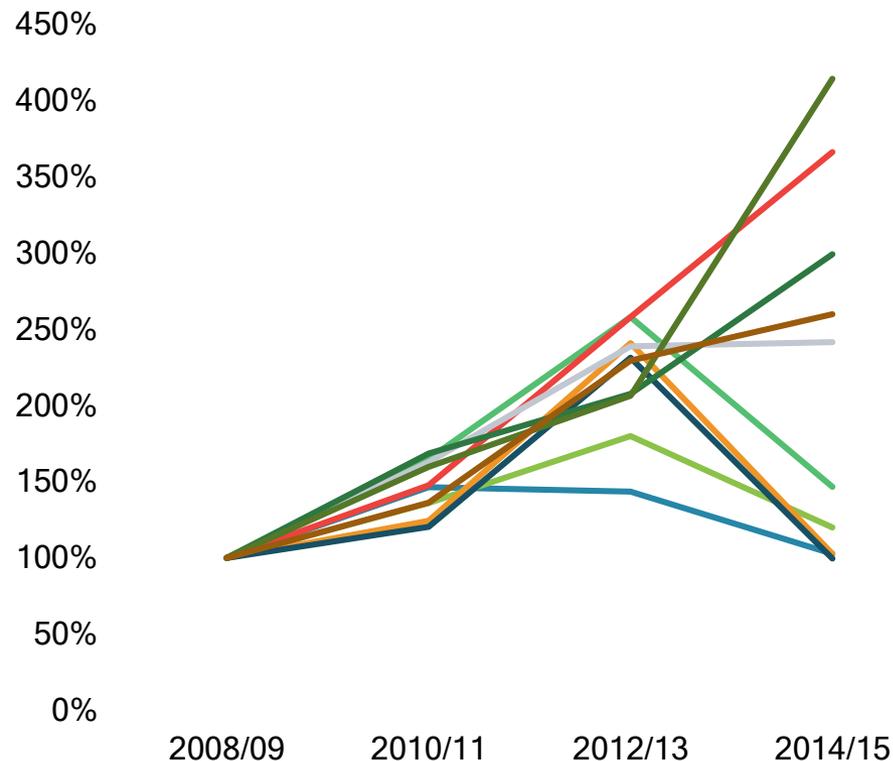
### Wage rate index: 10 highest rental use regions



Wage rate (index: 2008/09 = 100)

- Kilimanjaro
- Pwani
- Mbeya
- Mwanza
- Arusha
- Dodoma
- Iringa
- Morogoro
- Manyara
- Mara

### Tractor rental cost index: 10 highest rental use regions



Tractor rental cost (index: 2008/09 = 100)

- Kilimanjaro
- Pwani
- Mbeya
- Mwanza
- Arusha
- Dodoma
- Iringa
- Morogoro
- Manyara
- Mara