PROFITABILITY OF FERTILIZER USE IN SUB-SAHARAN AFRICA: EVIDENCE FROM MALAWI

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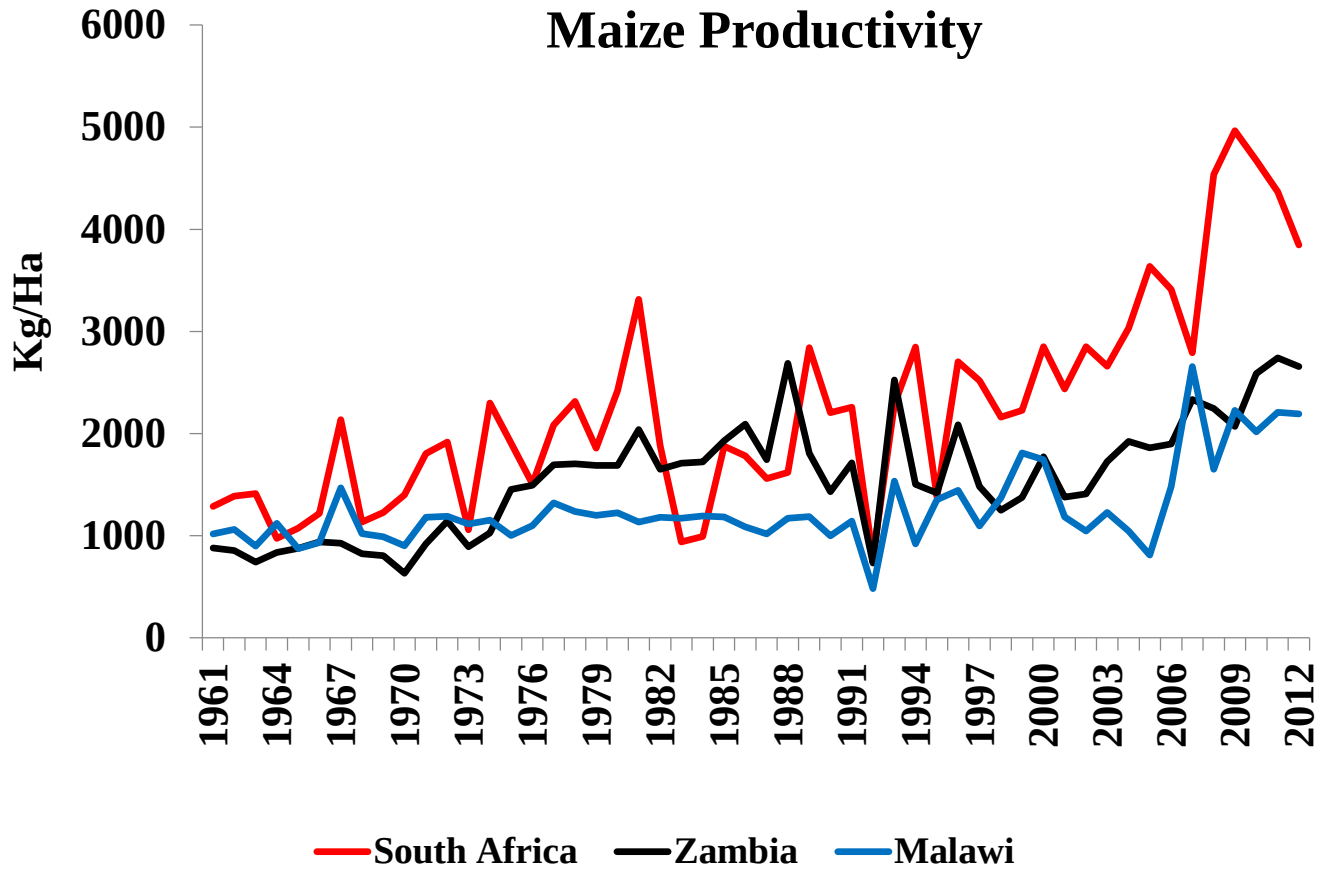
Motivation

- Agricultural productivity in Malawi has room for improvement (MoAFS, 2011; Kilic et al., 2013)

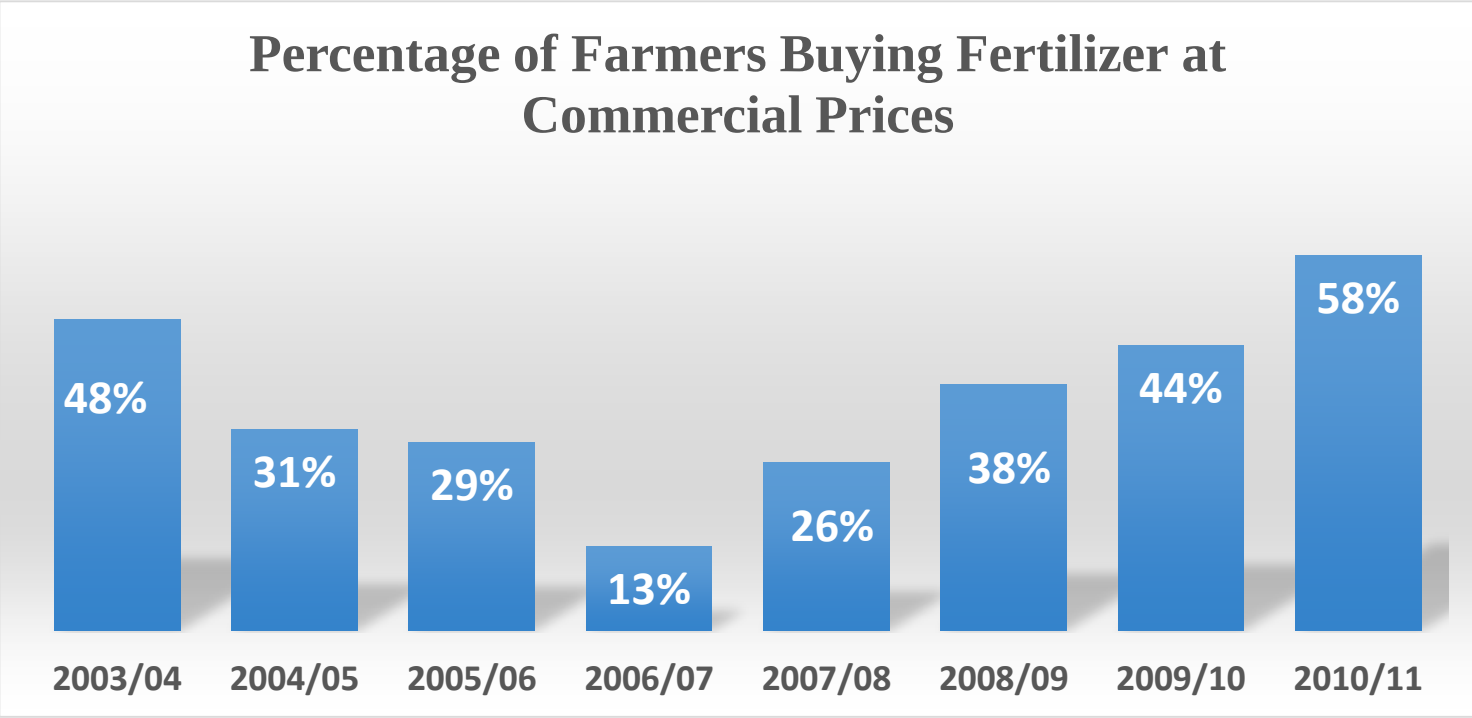


Yield Gap = 38% to 53% for cereals (MoAFS, 2011)

Motivation

- Low productivity among smallholders often attributed to:

1. Limited utilization of modern farm inputs, particularly inorganic fertilizer and improved seeds (MoAFS, 2011; Daudi, 2007).



Source: IHS2, AISS1, AISS2, AISS4 data

- Commercial fertilizer use increasing in Malawi.
- But relatively limited use of inorganic fertilizer and improved seed could be because they are unprofitable or marginally profitable in expectation for many farmers

Research Questions

- What is the level of NUE, and how does it vary across regions & districts in Malawi?
  - NUE = Kg Maize/Kg Nitrogen (MPP of N)
- To what extent is fertilizer profitable, and how does it vary across space?
- Is the government recommended rate of fertilizer application profitable?

Contribution

- Gardens tracked over time: Garden (a piece of continuous land that contains one or more plots)
  - Use garden FE to control for unobservable time-invariant soil fertility characteristics
  - Builds on similar studies by Xu et al. (2008), Sheahan et al. (2014), Harou et al. (2015)

- Hierarchical model estimator to measure plot-specific NUE

- Help the government to form policies to boost the adoption of fertilizer and hence improve agricultural productivity

- Help in the geographical targeting of the Farm Input Subsidy Program (FISP)

Data:

- Two-wave panel data collected by NSO of Malawi with World Bank support
  - IHS3 : 2010/2011 ag. year (3246 HHs)
  - IHPS : 2012/2013 ag. year (4000 HHs)
  - Dropped non-ag HHs
  - Dropped urban HHs

Methodology: Approach

- Measure of profitability: Marginal Value Cost Ratio (MVCR)

$$MVCR = NUE * \frac{P_{maize}}{P_{nitrogen}}$$

- Three prices of maize:

  Farm gate harvest season price

  Lean season market price

  Import parity price

- Decision: depends on assumption about transaction cost

1. No transaction cost: Profitable if MVCR >=1
2. Positive transaction cost: Profitable if MVCR >=2

Methodology: Approach

How is NUE estimated? Production function

$$Y = f(N, Z)$$

Estimators: 1)Fixed-effects

a) Garden
b) Household
c) Enumeration area
d) District

2) Multilevel:

a) Level 1 = plots; Level 2 = HH
b) Level 1 = plots; Level 2 = garden

Methodology: Estimation strategy

- **Estimating equation**

$$Y_{ijt} = \boldsymbol{\beta_1 N_{ijt}} + X_{ijt}\beta_x + H_{ijt}\beta_h + W_{ijt}\beta_w + \varepsilon_{ijt}$$

$$\varepsilon_{ijt} = c_j + v_{ijt}$$

Where *i* = plot; *t* = time; and *j* = garden, HH, EA or district

$\widehat{\boldsymbol{\beta_1}}$ = NUE estimate

- **Multilevel model:**

Plot level: $Y_{ph} = \beta_{0h} + \boldsymbol{\beta_{1h} N_{ph}} + X_{ph}\beta_x + \varepsilon_{ph}$

Household level: $\beta_{0h} = \beta_{00} + H_h\alpha_{0m0} + U_{0h}$

$$\beta_{1h} = \beta_{10} + U_{1h}$$

Full model: $Y_{ph} = \beta_{00} + \boldsymbol{\beta_{10} N_{ph}} + X_{ph}\beta_k + H_h\alpha_{0m0} + \left(U_{0h} + \boldsymbol{U_{1h} N_{ph}} + \varepsilon_{ph}\right)$

Methodology: Identification strategy

Endogeneity concerns? Likely due to omitted variables

- People don't acquire fertilizer randomly
- People don't apply fertilizer to plots randomly.

- Use of FE at different levels of aggregation from district to garden allows us to control for correlation between **N and c_j** in estimating equation
  - District and household bias may cause an overestimation of NUE effect
  - Garden-level bias may cause an over or underestimation of NUE

- Rich set of controls to deal with correlation between **N and v_{ijt}**

Results: NUE estimates across estimators

		Estimates
OLS		12.09*** (1.70)
Fixed-effects estimators	Garden	11.21*** (3.17)
	Household	9.24*** (2.25)
	Enumeration area	10.64*** (1.74)
	District	11.28*** (1.68)
Multilevel estimators	Level 1 = plots; level 2 = garden	11.89*** (1.52)
	Level 1 = plots; level 2 = household	11.55*** (1.48)

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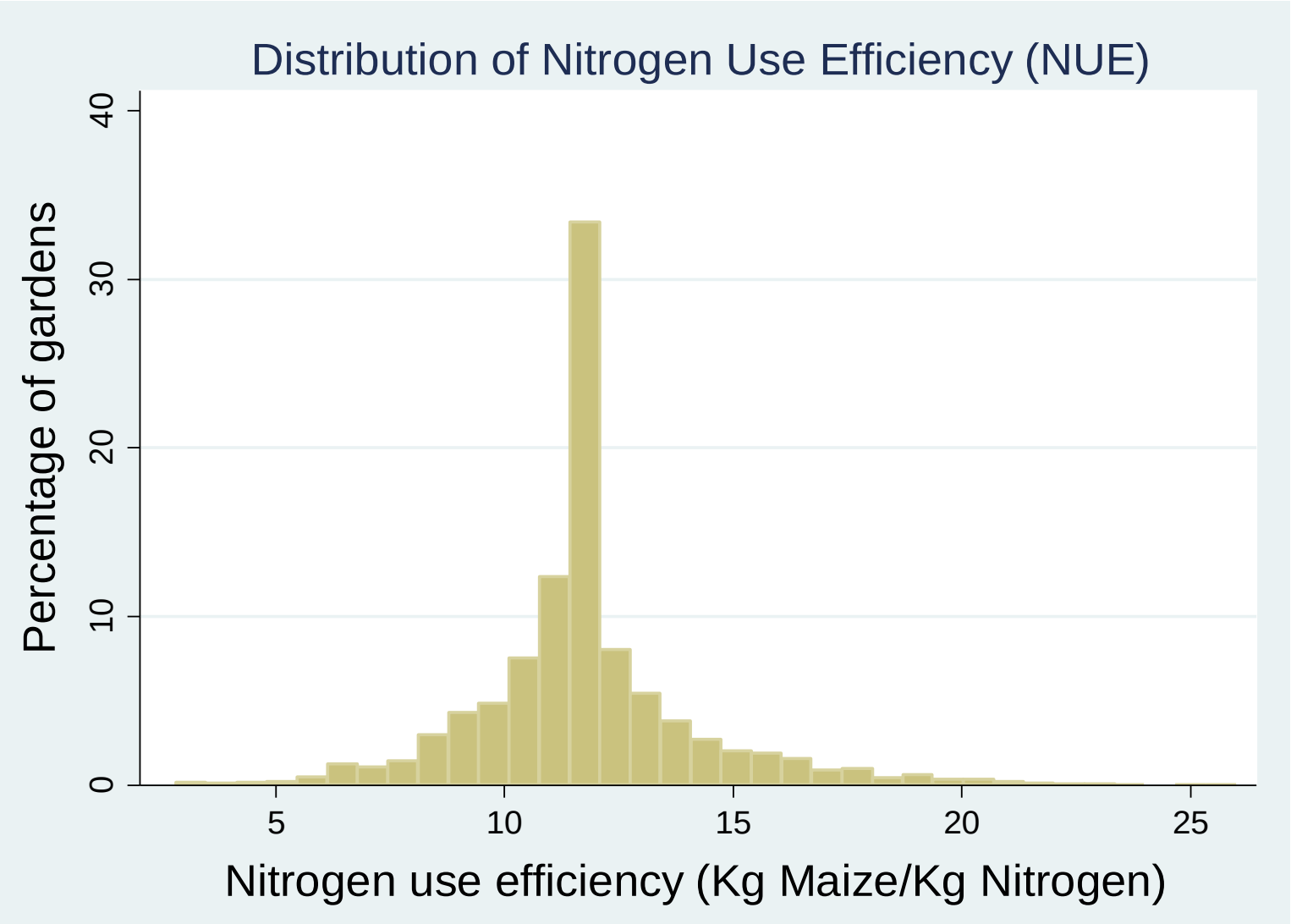
Results: Distribution of NUE



Mean = 11.89

Min = 2.82

Max = 25.98

SD: 2.42

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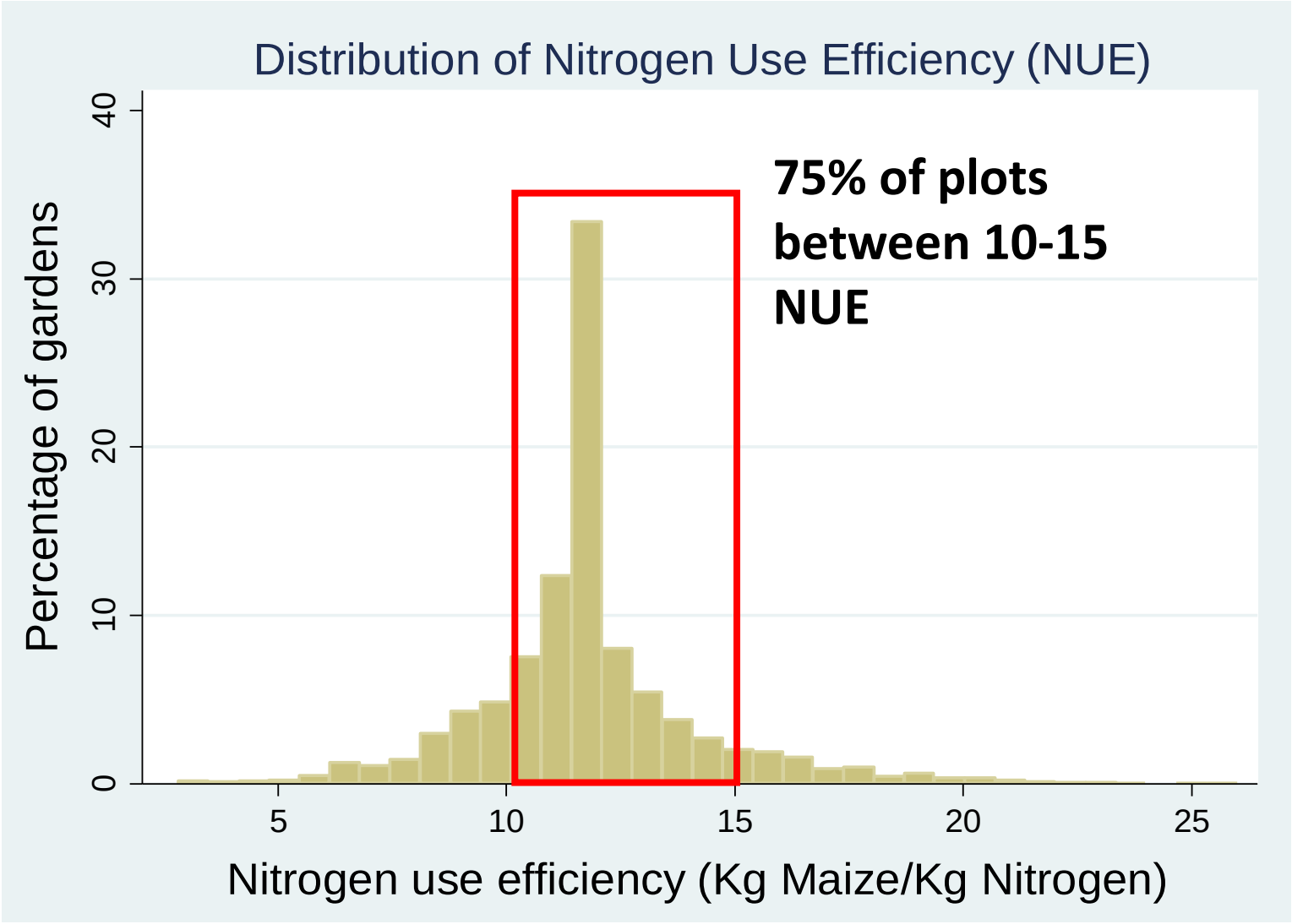

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Min = 2.82

Max = 25.98

SD: 2.42

Results: Distribution of NUE

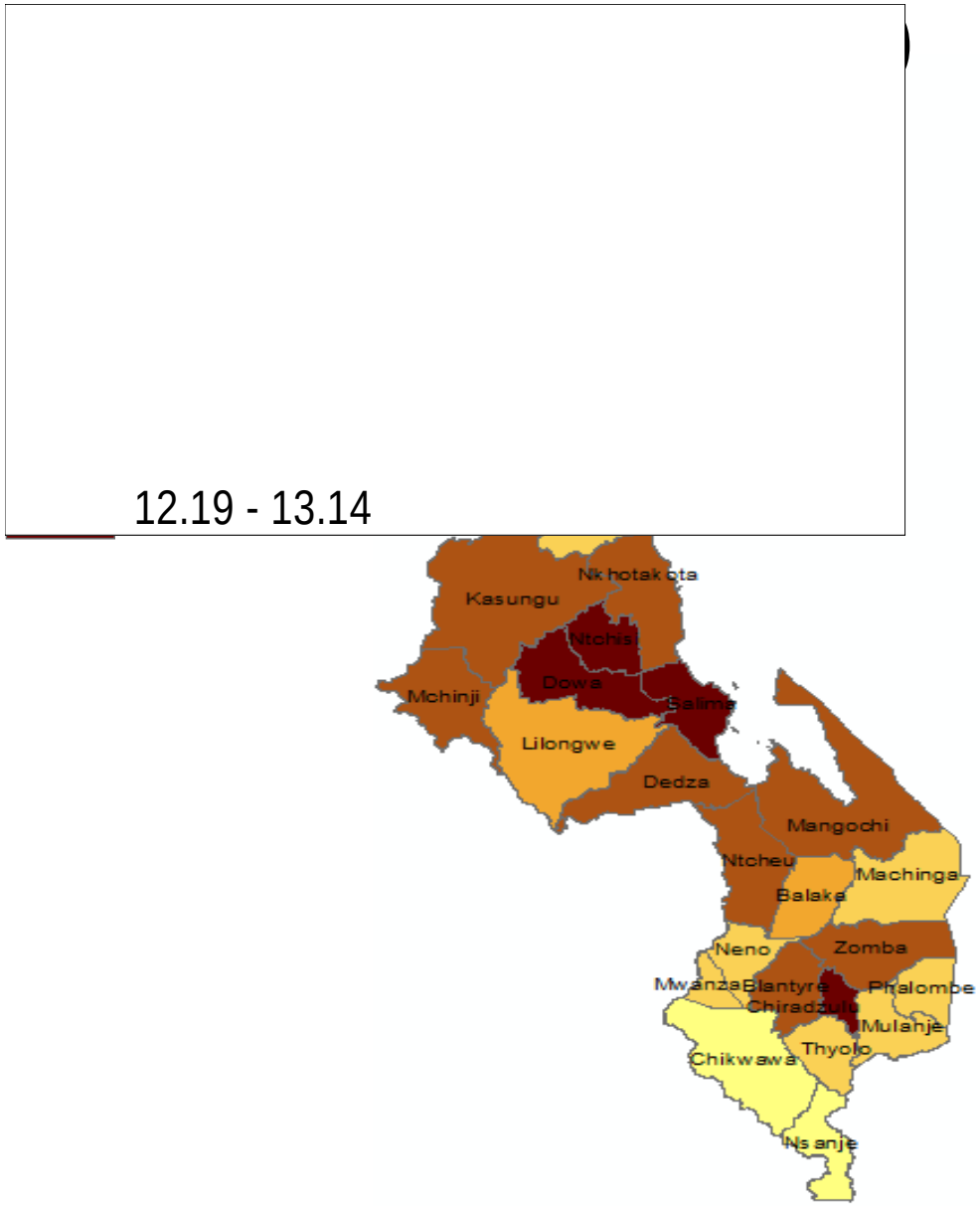
- Average NUE of 11.89 for Malawi is low

- …but not an isolated case in SSA:

  NUE in Nigeria: 8 to 13 (Liverpool-Tasie et al., 2015)

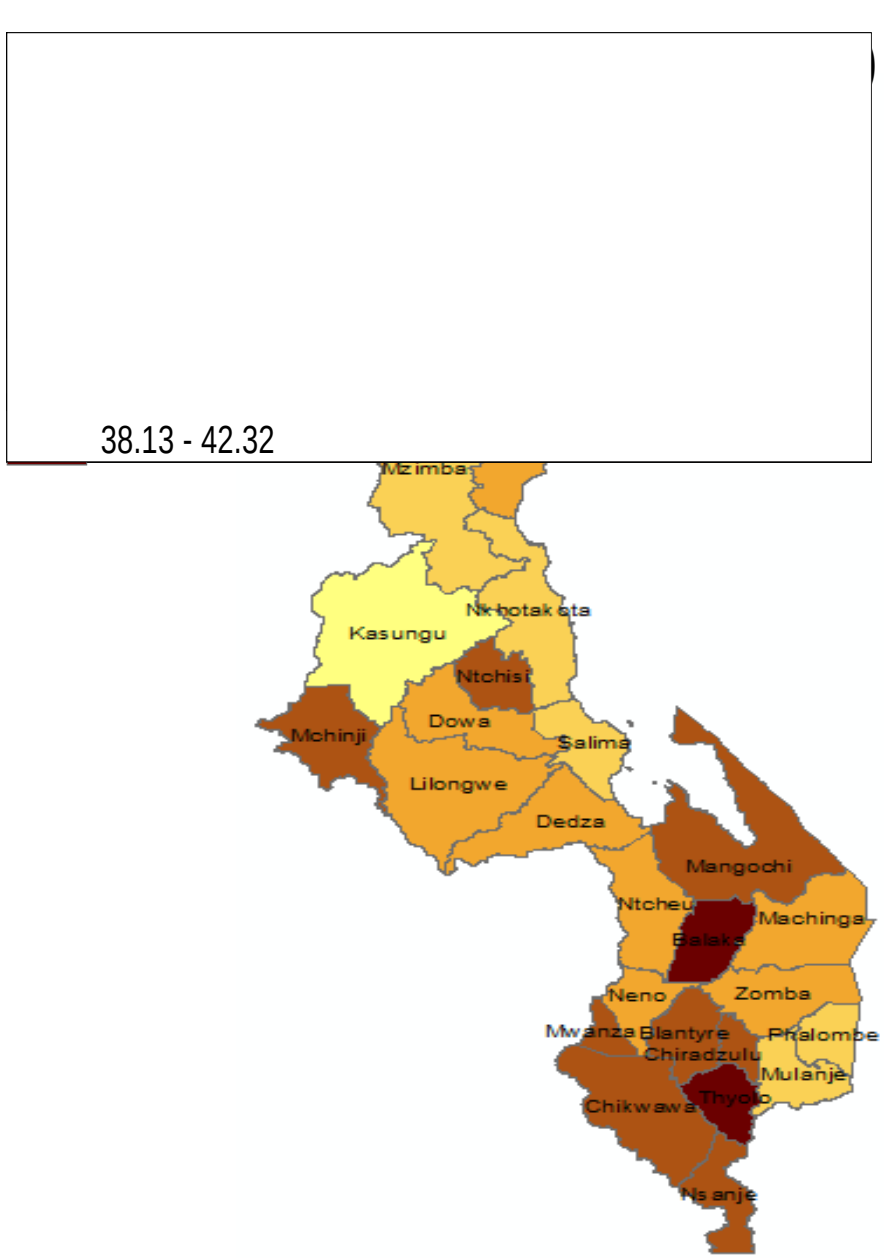
  NUE in Kenya: 11 to 20 (Sheahan et al., 2013)

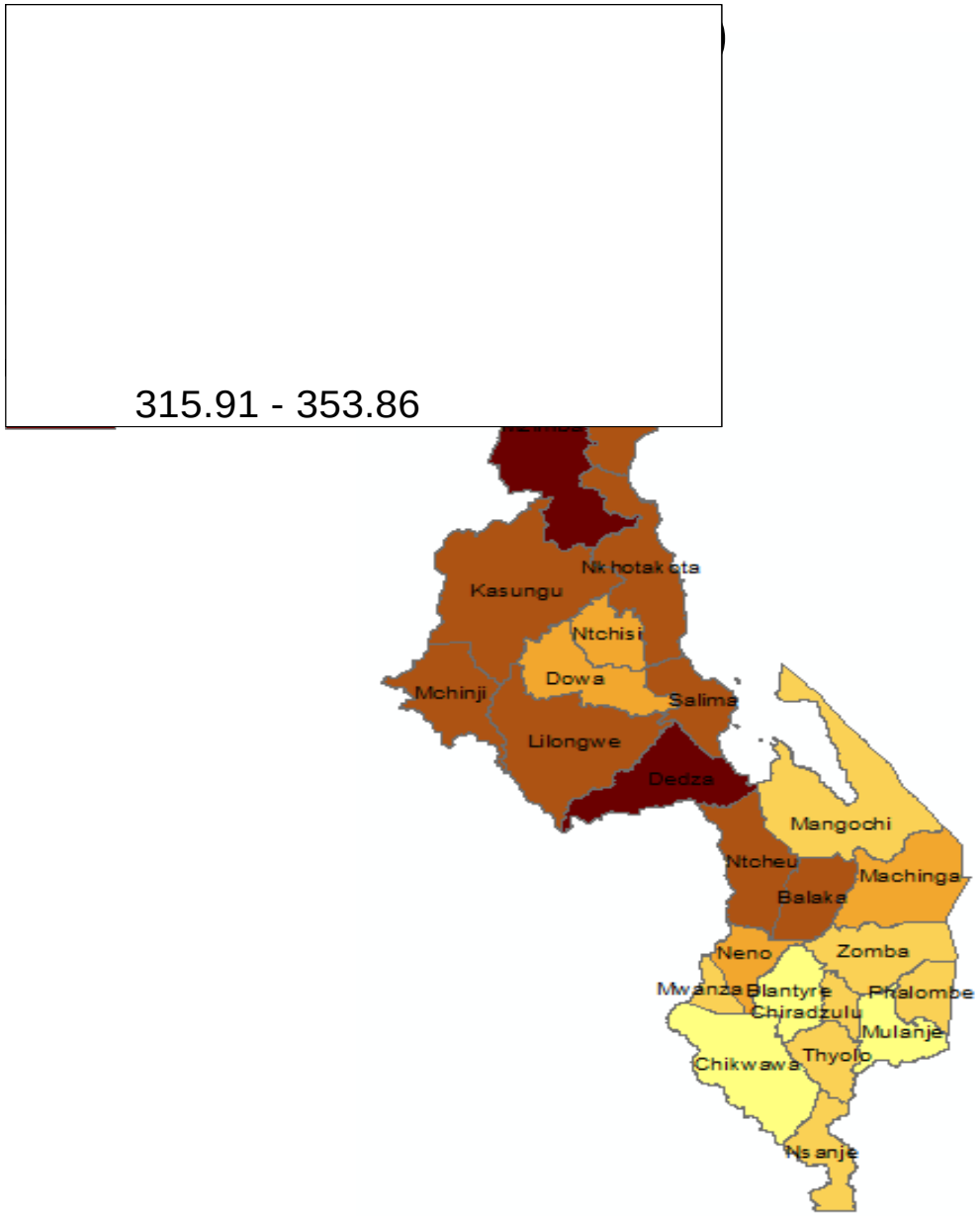
Results: Distribution of NUE at District Level



NUE Category	Districts
	Ntchisi, Dowa, Salima, Chiradzulu
	Chitipa, Karonga, Kasungu, Nkhotakota, Mchinji, Dedza, Moangochi, Ntcheu, Zomba and Blantyre
	Nkhata Bay, Lilongwe and Balaka
	Rumphi, Mzimba, Machinga, Neno, Mwanza, Thyolo, Mulanje, Phalombe
	Nsanje, Chikwawa

Results: Distribution of maize and nitrogen prices



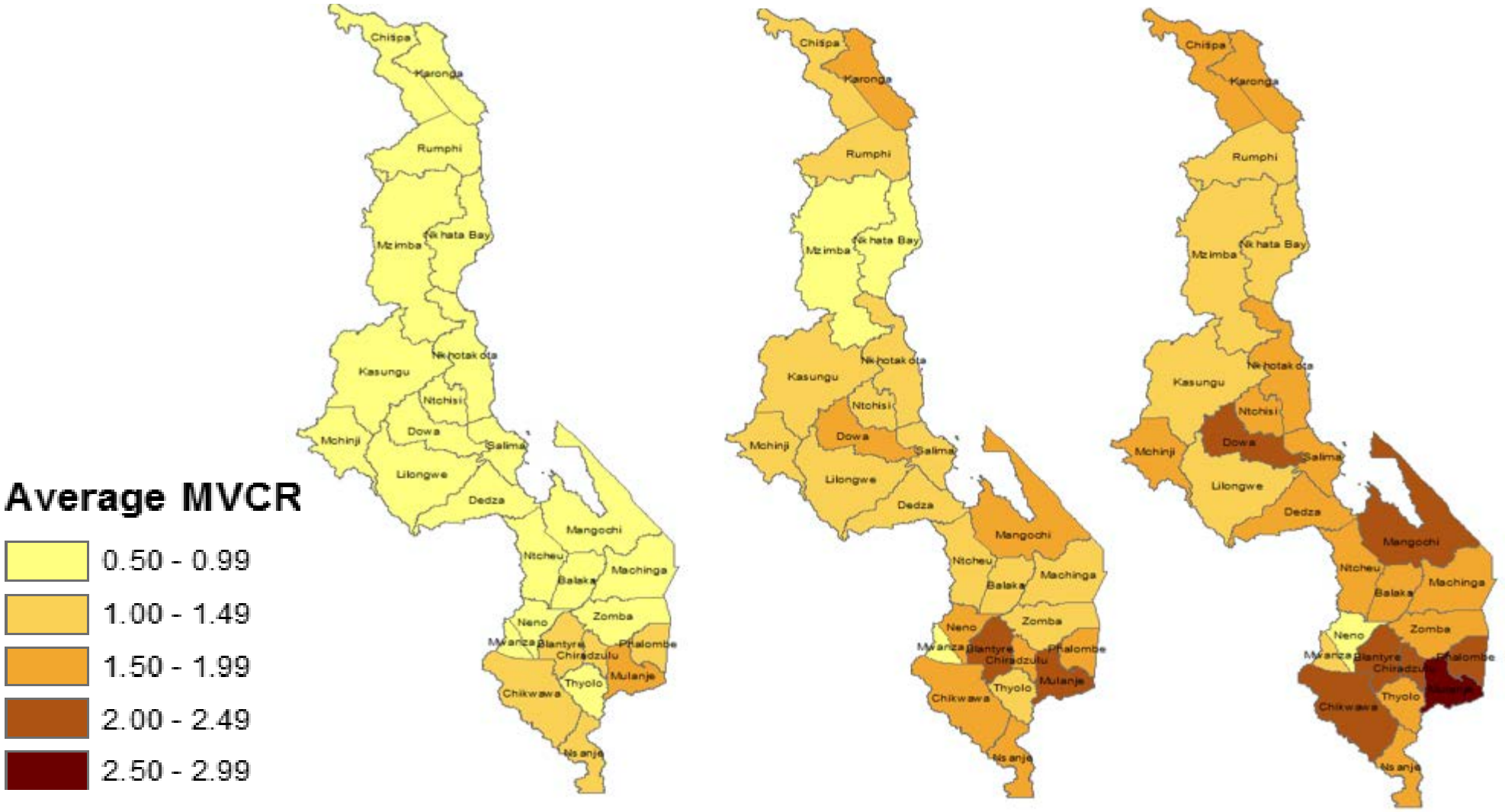


Results: Profitability across districts

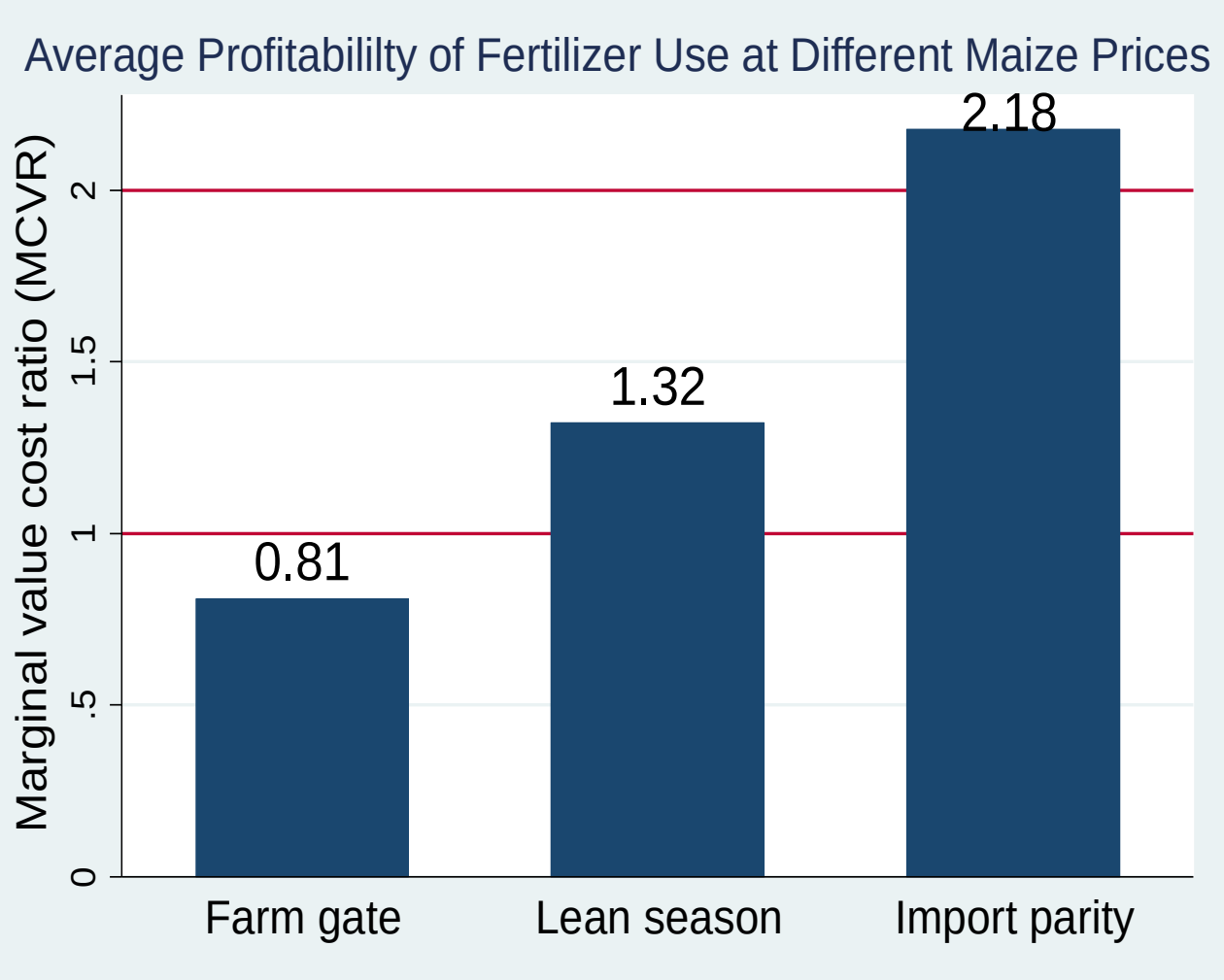
Farm gate price of maize

Lean season market price of maize

Import price of maize



Results: Average Profitability

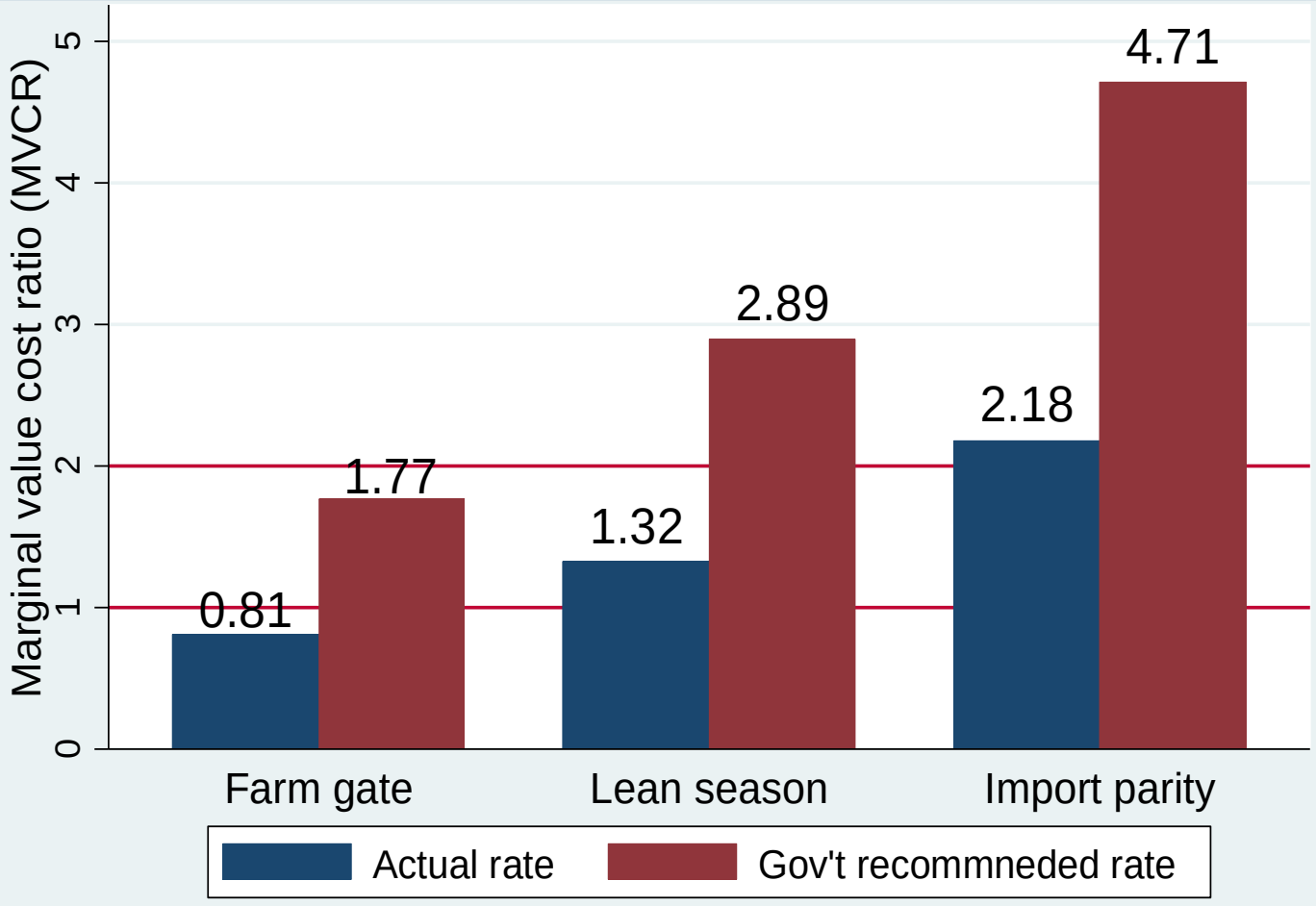


Is the use of fertilizer profitable?

	Maize price		
	Farm gate	Lean season market	Import parity
No transaction cost (MVCR >=1)	No	Yes	Yes
Positive transaction cost (MVCR >=2)	No	No	Yes

Results: Profitability of recommended N rate

Gov't rate is over 100% more profitable



Govm't rec. rate	Actual rate (mean)
35 kg/ha	15.27 kg/ha
69 kg/ha	45.66 kg/ha
92 kg/ha	48.06 kg/ha

Actual is 51% to 129% lower

Conclusions

- NUE is low in Malawi and has room for improvement
- **Central & Northern (southern)** region with **highest (lowest)** NUE have **lowest(highest)** level of fertilizer profitability.
  - Driven by relative maize and fertilizer prices
- It is more profitable for the average smallholder to use fertilizer when considering lean season maize price as his/her opportunity cost.
- Government perspective: IPP of maize may be the cost that they find relevant
- Extension issue: encourage farmers to follow Ministry recommendations to increase NUE.
  - Concern that subsidy may crowd out other extension activities.

Thank you for your time!

Questions/Comments

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VARIABLES	OLS	EA FE	District FE	HH FE	Garden FE	Multilevel models (Level 1 = Plot) Level 2 = HH	Level 2 = Garden
N application rate (Kg/ha)	12.092***	10.637***	11.284***	9.237***	11.213***	11.552***	11.887***
	(1.698)	(1.741)	(1.678)	(2.248)	(3.174)	(1.484)	(1.521)
Nitrogen application rate (Kg/ha) squared	-0.017	-0.015	-0.016	-0.014	-0.027	-0.017*	-0.018*
	(0.011)	(0.011)	(0.010)	(0.013)	(0.016)	(0.009)	(0.009)
Below recommended N application rate	59.641	-4.043	21.955	-14.258	57.552	69.972	82.740
	(83.920)	(83.399)	(83.242)	(87.246)	(100.810)	(76.992)	(78.777)
Above recommended N application rate	-281.236***	-214.159**	-240.122***	-199.043**	-236.136***	-211.968**	-233.993***
	(93.450)	(87.359)	(86.948)	(92.964)	(62.194)	(84.074)	(88.874)
Applied basal fertilizer on time	153.624***	114.642***	114.864***	184.009***	171.070**	172.323***	169.239***
	(39.746)	(40.853)	(41.541)	(66.360)	(78.907)	(40.290)	(36.331)
Fertilizer used is basal fertilizer	194.653***	224.489***	206.447***	196.515***	259.993***	180.716***	182.223***
	(38.478)	(36.026)	(37.399)	(49.299)	(73.855)	(34.260)	(33.186)
Applied organic fertilizer	132.084**	135.516***	132.407***	121.343**	87.521**	136.256***	126.458***
	(51.262)	(43.187)	(47.636)	(52.494)	(36.686)	(42.020)	(40.595)
Seed rate (Kg/ha)	3.769***	3.314***	3.164***	3.651***	2.513*	3.625***	3.453***
	(0.920)	(0.870)	(0.892)	(0.951)	(1.293)	(0.809)	(0.789)
Used hybrid seed	31.985	38.291	26.574	51.413	136.536*	30.901	40.850
	(33.965)	(29.982)	(33.007)	(38.839)	(69.693)	(30.243)	(30.724)
Pure stand	-86.076**	-174.341***	-175.919***	-191.329***	-210.800***	-109.635***	-101.360***
	(40.030)	(36.081)	(34.995)	(42.867)	(48.028)	(31.010)	(30.209)
Plot size (ha)	-676.112***	-883.008***	-894.862***	-1,401.012***	-1,800.821***	-916.596***	-847.798***
	(222.339)	(235.539)	(214.805)	(350.108)	(395.619)	(189.547)	(183.287)
Plot size (ha) squared	193.891	275.557*	273.539*	581.543**	752.706**	344.274***	286.124**
	(146.553)	(163.325)	(152.918)	(259.038)	(314.832)	(130.718)	(127.525)
Labor (days)	0.925***	0.913***	0.934***	0.952***	0.962***	0.942***	0.950***
	(0.209)	(0.206)	(0.207)	(0.268)	(0.282)	(0.197)	(0.183)
Soil is of good quality	283.499***	219.820***	239.698***	168.253***	178.885**	253.805***	259.843***
	(50.273)	(50.062)	(48.692)	(54.691)	(75.471)	(41.783)	(41.783)
Soil is of fair quality	173.437***	147.593***	156.578***	181.907***	230.479***	179.355***	179.136***
	(50.434)	(43.679)	(44.756)	(49.679)	(62.539)	(40.327)	(40.557)
Plot is not flat	-47.802	-44.742	-41.290	-76.431*	-78.986	-59.257*	-53.645*
	(35.259)	(34.091)	(35.148)	(39.650)	(66.640)	(31.338)	(31.160)
Plot is swampy	-5.287	-33.823	-8.920	-83.808	-115.656	-32.024	-26.390
	(38.283)	(37.309)	(35.238)	(52.386)	(89.498)	(40.500)	(39.466)
Soil is sandy clay	25.051	33.122	33.361	-13.825	-8.740	24.675	29.723
	(35.023)	(33.549)	(31.709)	(38.385)	(57.240)	(30.402)	(29.994)
Plot show signs of erosion	38.679	-11.732	-15.097	5.421	46.803	31.250	41.151
	(46.275)	(43.577)	(42.716)	(53.265)	(45.854)	(36.397)	(34.315)
Female plot manager	-102.625***	-107.605***	-90.399**	-150.468**	-198.198**	-111.814***	-113.273***
	(36.295)	(36.724)	(35.365)	(63.280)	(82.736)	(34.716)	(32.751)
Age of plot manager	-1.483	-0.993	-1.201	2.853	0.612	-0.704	-1.126
	(1.377)	(1.275)	(1.285)	(1.939)	(2.211)	(1.185)	(1.106)
Years of education of plot manager	13.855***	8.181*	10.930**	8.614	-7.623	10.638**	10.353**
	(5.201)	(4.752)	(4.830)	(10.485)	(12.591)	(5.020)	(4.674)
African Adult Male Equivalent	-5.412	-0.071	-2.932	10.825	29.695	-5.356	-5.070
	(13.647)	(14.650)	(13.647)	(27.334)	(38.042)	(12.150)	(10.909)
Dependency ratio	0.289	0.245	0.215	0.226	0.046	0.298	0.249
	(0.195)	(0.188)	(0.183)	(0.286)	(0.272)	(0.197)	(0.186)
Distance to boma	0.481	-0.455	-0.354	-0.809	-0.219	0.068	0.373
	(0.803)	(0.885)	(0.896)	(0.983)	(1.314)	(0.616)	(0.568)
Index of ownership of agricultural tools	77.715***	52.832***	67.763***	-6.816	-7.012	56.861***	68.958***
	(19.448)	(13.962)	(17.097)	(19.674)	(28.193)	(14.832)	(13.108)
Index of ownership of durable goods	88.175***	98.621***	92.435***	83.865***	108.644***	92.980***	93.727***
	(15.353)	(15.597)	(15.075)	(27.362)	(30.276)	(13.880)	(12.545)
Annual mean rainfall(mm)	0.815**	1.472	0.903	3.411*	3.403	1.049***	1.006***
	(0.374)	(1.116)	(0.599)	(1.871)	(3.007)	(0.250)	(0.236)
Annual mean temperature (°C * 10)	-8.853***	-5.212	-4.313*	-10.718	-17.927	-7.751***	-7.841***
	(1.897)	(3.797)	(2.587)	(6.943)	(12.535)	(1.274)	(1.204)
Year (2013)	347.955***	307.908***	313.956***	272.768***	263.957***	317.304***	317.289***
	(40.732)	(42.329)	(43.804)	(48.234)	(45.960)	(33.288)	(30.993)
Agro-ecological zone fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1,662.699***	810.346	980.193	524.097	2,302.636	1,424.072***	1,428.150***
	(598.780)	(1,294.931)	(867.096)	(2,492.269)	(4,859.146)	(409.097)	(380.119)
Observations	4,913	4,913	4,913	4,913	4,913	4,913	4,913
R-squared	0.283	0.246	0.318	0.226	0.247	--	--
Number of groups	--	194	26	2,135	3,365	2,135	3,365