Are Farmers Under-Utilizing Fertilizer? Evidence from Kenya

Megan Sheahan, Roy Black, T.S. Jayne

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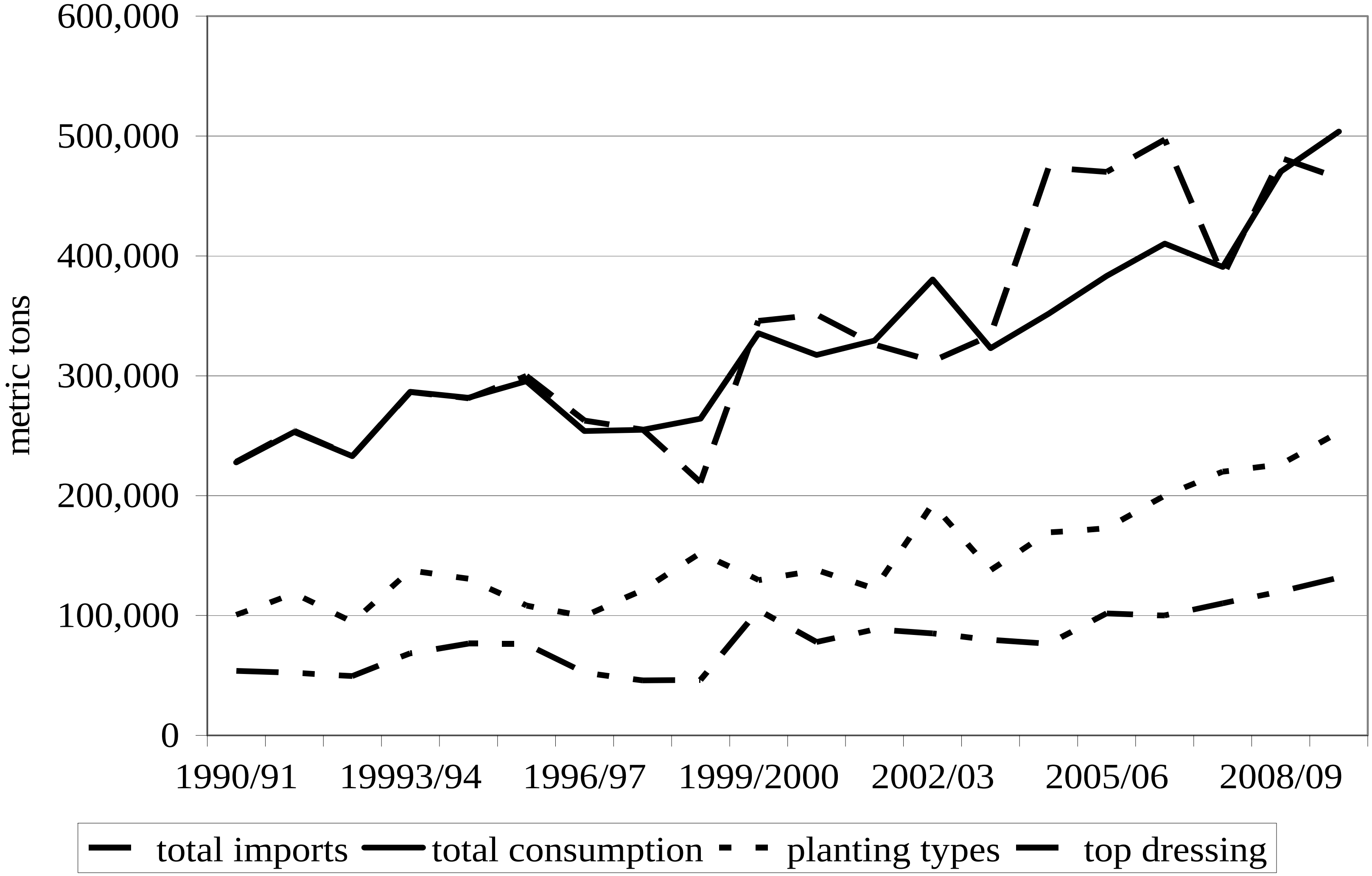
1- Introduction

- Motivation
  – Increased attention to fertilizer use in sub-Saharan Africa manifested, most visibly, in the form of renewed government subsidy programs
  – Despite upward trends in fertilizer use in Kenya since market liberalization in the mid-1990s, there is still a common conception that fertilizer use is not expanding quickly enough
  – Little evidence exists that explores the profitability of higher fertilizer application rates or expanding fertilizer use beyond what is already observed in Kenya at a disaggregated level to back-up these commonly held claims

National Level Fertilizer Consumption and Imports over Time



Source: Ministry of Agriculture, Kenya

1- Introduction

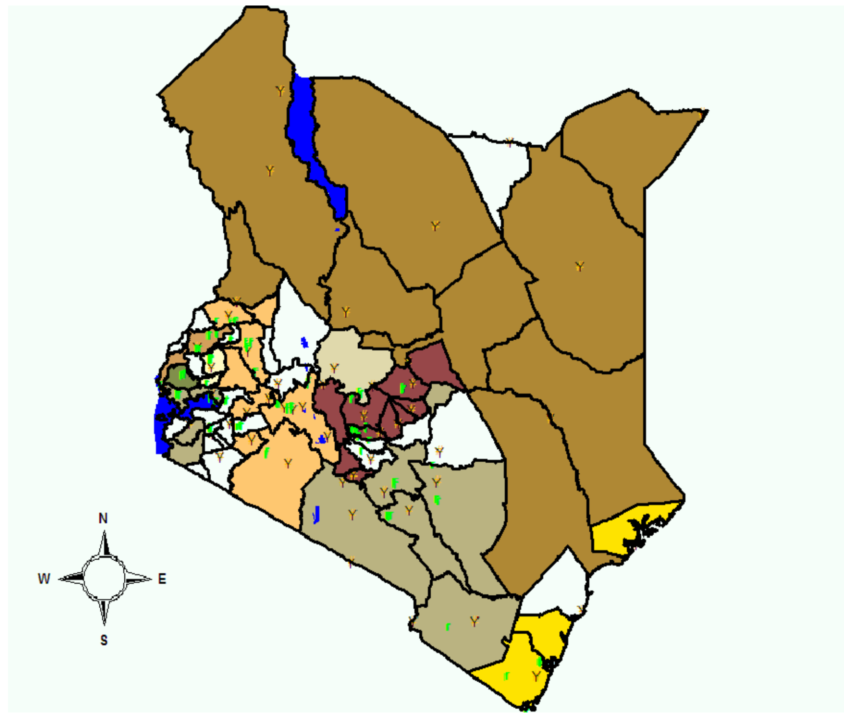
- Existing Literature: Kenya specific
  - Hassan, Murithi, and Kamau (1998): experiment station data from the late 1980s to study fertilizer profitability
  - Wanderi et al. (2011); Delve and Probert (2004); Bationo (2004): agronomy literature using designed experiments and computer systems models
  - Marenya and Barrett (2009): small geographic area with one cross section to study minimum level of soil organic matter necessary for plant responsiveness to fertilizer application
  - Duflo, Kremer, and Robinson (2008, 2011): controlled field experiments with a small number of prescribed fertilizer rates in another small area of western Kenya and calculates rates of return to those application rates
  - Matsumoto and Yamano (2011): two-year panel of observational data focused on western and central Kenya

1- Introduction

- Research questions
  1. How does the response of maize to fertilizer application rates vary across Kenya?
  2. Are households in Kenya using fertilizer on maize fields where it is profitable to do so, and is there room for profitably expanding fertilizer use in certain areas?
  3. What are economically optimal levels of fertilizer application, and does a “gap” exist between observed and estimated optimal levels?

2- Data

- Tegemeo Rural Household Survey for the years 1997, 2000, 2004, 2007 and 2010
- 24 administrative districts, 39 divisions and 120 villages
- 1540 households in 1997 with 1243 remaining through the final 2010 wave



2- Data

"Maize field" as unit of analysis

- Maize and no more than 6 other crops
- No major cash crop (tea, sisal, rice, pyrethrum, cotton)
- Maize constitutes >=25% value of harvest from field

3- Conceptual Framework and Methodology

- Conceptual Framework
  - Households function as multiproduct firms (income from on-farm and off-farm activities)
  - Households are optimizers subject to constraints across all activities
  - Our “activity” of focus is the maize enterprise (maize fields, as previously defined)

3- Conceptual Framework and Methodology

- Methodology
  1. Estimate a maize production function:

$$Y_{ijt} = f(x_{kijt}, z_{kijt}, \mu_{kijt})$$

    - Maize yield estimated using Liu and Myer's output index (2009)
    - Quadratic functional form (Berck and Helfand 1990, Kastens et al. 2005, Traxler and Byerlee 1993, Kouka et al. 1995)
    - Correlated random effects (CRE) to control for unobserved household level heterogeneity portion of error term
    - Unbalanced panel allowed with CRE given linear model (Wooldridge 2010)
    - Compute robust standard errors clustered at the household level to account for heteroskedasticity and serial correlation (Wooldridge 2009)

3- Conceptual Framework and Methodology

- Methodology
  2. Calculate <u>expected</u> marginal and average value cost ratios (MVCRs and AVCRs) as measures of relative fertilizer profitability

$$E(MVCR_{fijt}) = \frac{E(p_{yt})E(MPP_{xijt})}{w_{fijt}}$$

Risk neutral	$E(AVCR_{fijt})>1$	↑ income as a result of fertilizer use
	$E(MVCR_{fijt})>1$	↑ income with ↑ rate of fertilizer application
Risk averse	$E(AVCR_{fijt})\geq 1+\rho$	↑ income as a result of fertilizer use
	$E(MVCR_{fijt})\geq 1+\rho$	↑ income with ↑ rate of fertilizer application

3. Calculate optimal fertilizer application rates where MVCR=1 and MVCR=2

3- Conceptual Framework and Methodology

- Methodology
  4. Calculate <u>expected</u> revenue added to maize production from fertilizer use as a measure of absolute fertilizer profitability

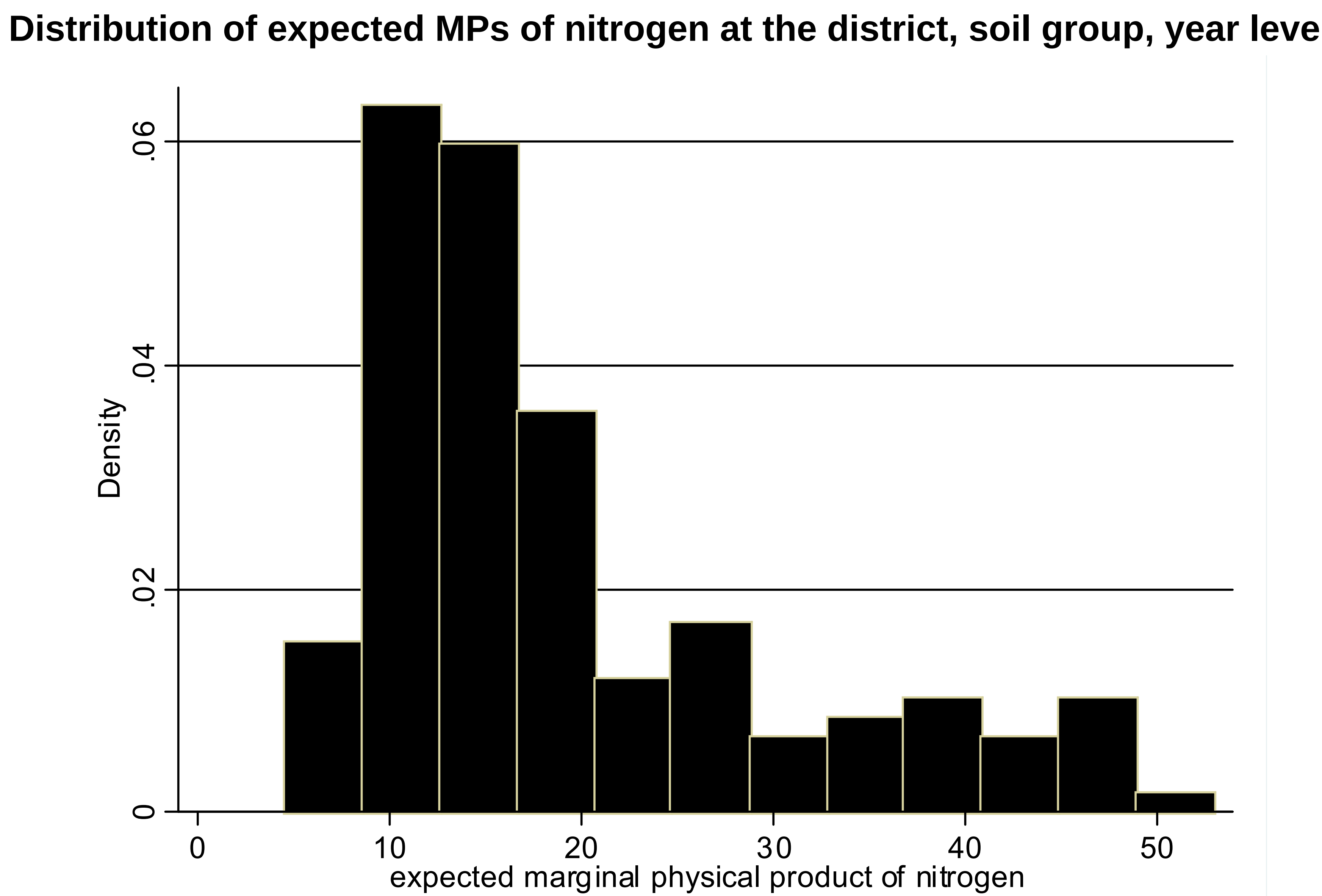
$$[E(Y^{F}) - E(Y^{NF})]E(p_{yt}) - x_{ijt}w_{fijt}$$

4- Maize Yield Response Model

- Applied nitrogen and phosphorous extracted from total fertilizer applied to plot. Estimates and remaining discussion focus on nitrogen.
- Nitrogen terms conditioned on (1) soil groups, (2) zone groups, (3) actual rainfall stress. Grouping system verified via Chow Test (p-value=0.0001).
- Other controls: number of crops on field, maize seed rate, hybrid seed, manure applied to field, legume on field, rainfall stress, asset wealth of household, field size
- Fixed effects: FAO soil type, district, year

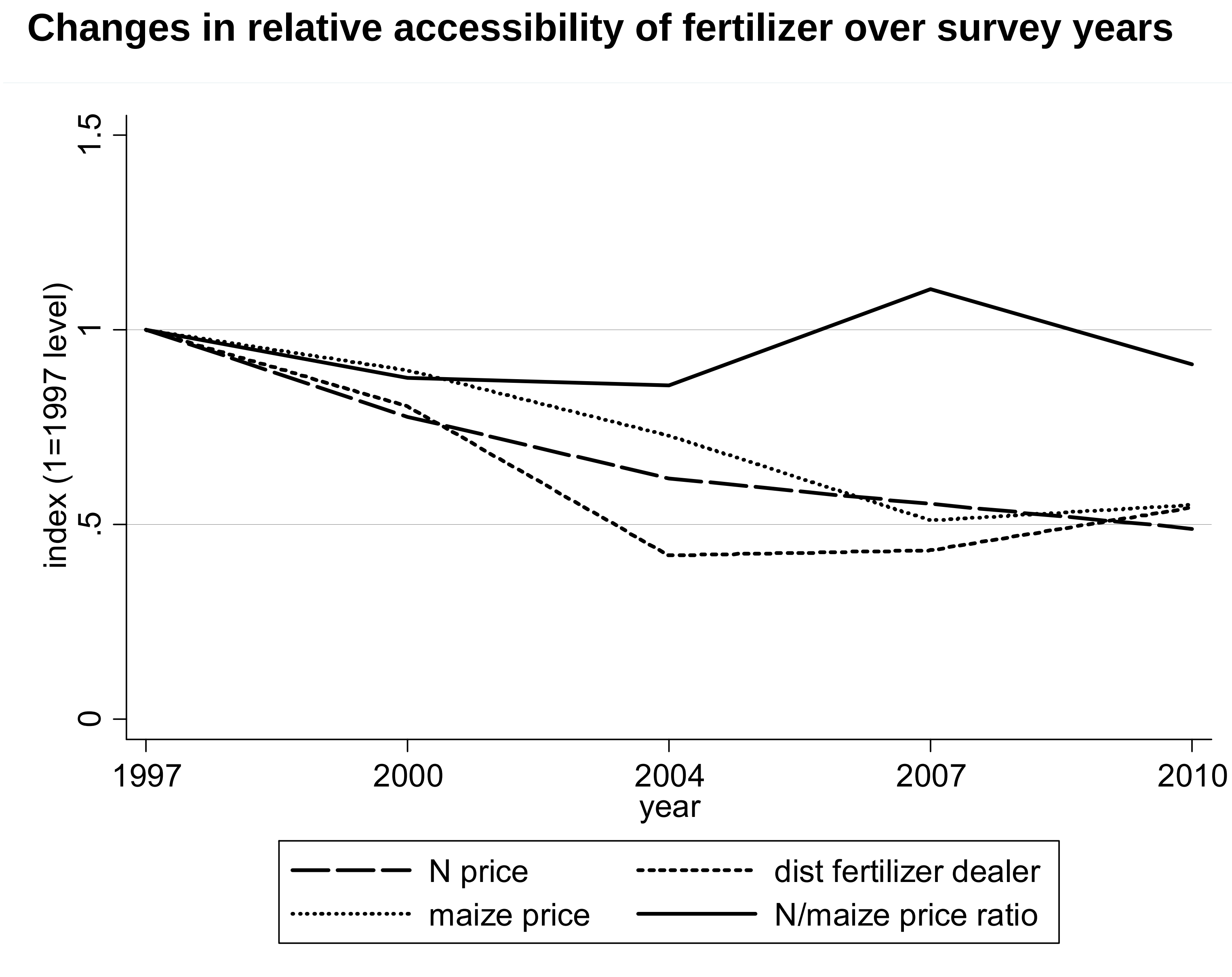
Production function results from coefficients on N terms

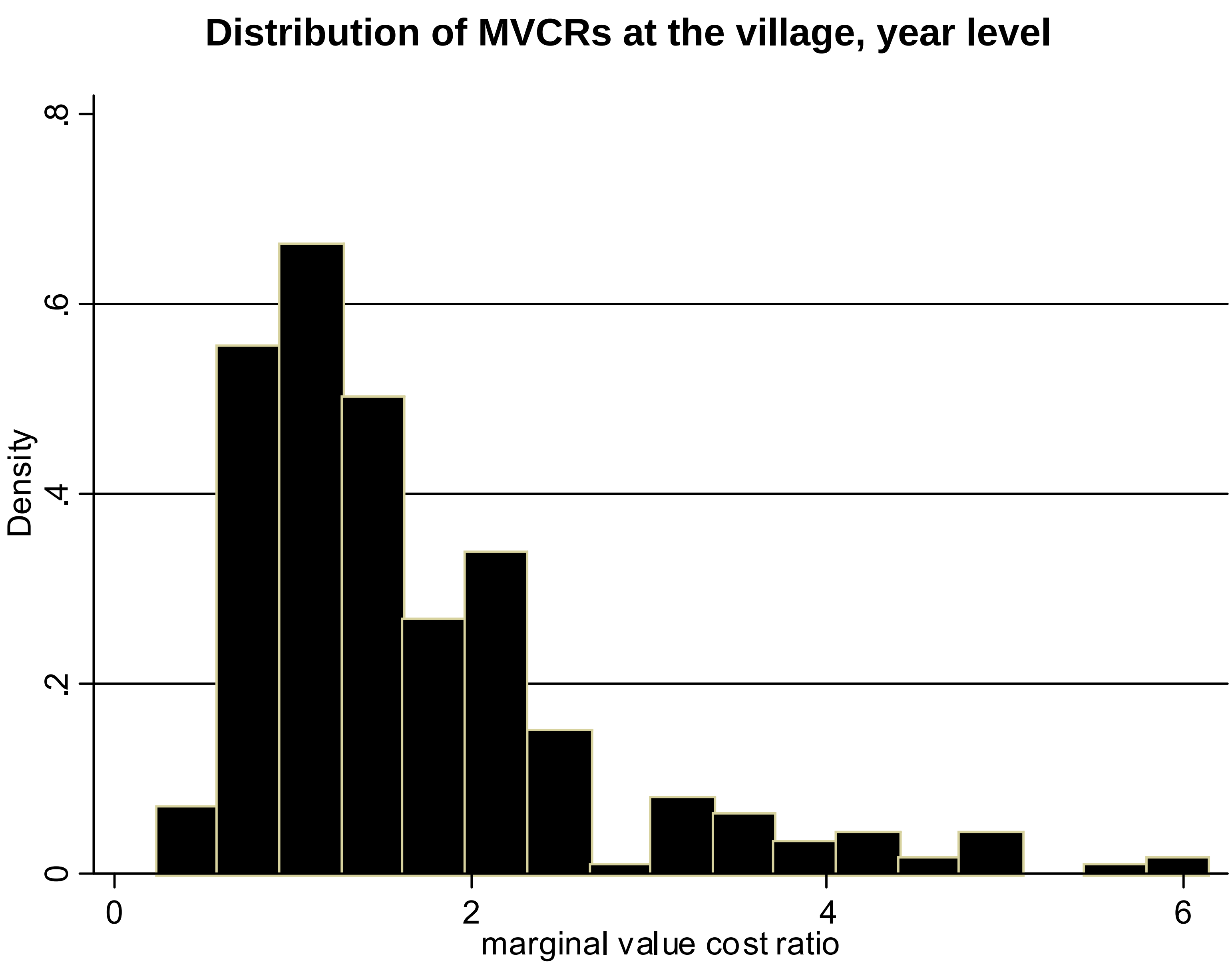
N*zone1 (lowlands)	25.45 (17.46)
N*zone2 (high potential areas)	17.58*** (4.90)
N*zone3 (highlands)	14.10** (6.63)
N^2*zone1 (lowlands)	-0.724*** (0.21)
N^2*zone2 (high potential areas)	-0.0938** (0.05)
N^2*zone3 (highlands)	-0.0889 (0.08)
N*P*zone1 (lowlands)	1.379*** (0.42)
N*P*zone2 (high potential areas)	0.256*** (0.08)
N*P*zone3 (highlands)	0.218 (0.15)
N*soil1 (volcanic landform soils)	-2.712 (3.83)
N*soil2 (high humus, productivity soils)	2.317 (3.11)
N*soil3 (Rankers with more sand)	-4.733 (3.17)
N*soil4 (Rankers with less sand)	Base
N*rainstress*zone1 (lowlands)	41.00* (21.43)
N*rainstress*zone2 (high potential areas)	-18.66** (7.42)
N*rainstress*zone3 (highlands)	17.82* (9.22)


Distribution of expected MPs of nitrogen at the district, soil group, year level
Density
0
.02
.04
.06
0
10
20
30
40
50
expected marginal physical product of nitrogen

5- Profitability of Fertilizer Use

- Price of nitrogen extracted from total price of fertilizer
- Calculate transport cost of fertilizer to nearest retailer → "acquisition price" of fertilizer
- Expected maize prices as estimated by Muyanga (forthcoming)
- Use selling and buying prices of maize given high number of net buyers


Changes in relative accessibility of fertilizer over survey years
index (1=1997 level)
0
.5
1
1.5
1997
2000
2004
2007
2010
year
N price
dist fertilizer dealer
maize price
N/maize price ratio


Distribution of MVCRs at the village, year level
Density
0
.2
.4
.6
.8
0
2
4
6
marginal value cost ratio

5-Profitability of Fertilizer Use

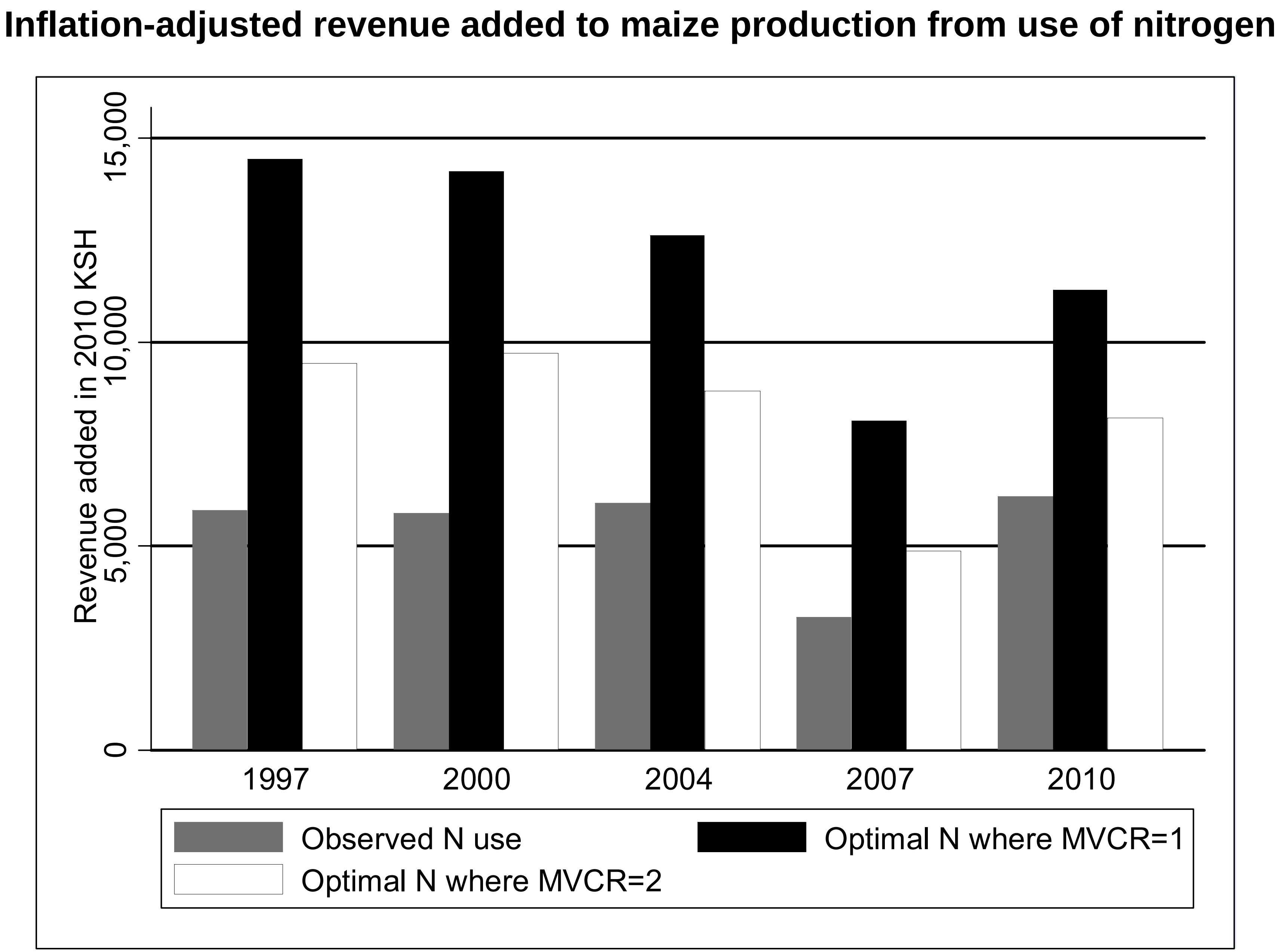
- Summary of results:
  - Eastern and Western Lowlands: appreciable increase in the percentage of fertilized fields in these districts over time as well as an increase in the rate of commercial nitrogen applied per hectare by fertilizer users, with a particularly large jump in 2010; fertilizer users in Machakos, Makueni and Mwingi applied at average rates near what we calculate to be optimal where MVCR=2 (<30% difference), although there is room to increase use by 5-10 kg/ha in order to achieve the condition MVCR=1 (30-50% above current rates)

5-Profitability of Fertilizer Use

- Summary of results:
  - Central and Western Highlands: estimated optimal nitrogen application levels for most of the highlands are unreasonably high where MVCR=1 (>60 kg/ha) due to lack of significant concavity in the production function; with average application rates in 2010 around 30-40 kg/ha in the highland areas, we cautiously conclude that fertilizer users are likely applying somewhere around optimal levels where profitable, although there appear to be opportunities to increase the percentage of farmers using fertilizer on maize in some areas, including the non-volcanic soil areas of Muranga district

5-Profitability of Fertilizer Use

- Summary of results:
  - High Potential Maize and Western Transitional Zones: households using fertilizer are already doing so at optimal or slightly more than optimal levels (consistent with the findings of Matsumoto and Yamano 2011); possible overuse of nitrogen fertilizers without appropriate complementary soil amendments in western Kenya leading to more acidic soils (Esipisu 2011); expanding fertilizer use beyond what is already observed is estimated to be unprofitable at market prices and fertilizer response levels prevailing over the sample period in these areas


Inflation-adjusted revenue added to maize production from use of nitrogen
Revenue added in 2010 KSH
0
5,000
10,000
15,000
1997
2000
2004
2007
2010
Observed N use
Optimal N where MVCR=1
Optimal N where MVCR=2

6- Conclusions

1- Fertilizer use at commercial prices is profitable across a large portion of Kenya’s maize producing areas.

2- Household commercial purchases have consistently and steadily increased towards risk-adjusted economically “optimal” levels of fertilizer application over the survey years

3- Tremendous additional expansion of average fertilizer application rates on maize in Kenya should not necessarily be sought after unless it is possible to raise the average physical response rates of maize to fertilizer

4- Focus should be on complementary inputs and attention to detail in soil conditions in order to raise the efficiency of fertilizer use on maize fields

5- In the few areas of Kenya where fertilizer use is still below calculated optimal levels, policy mechanisms may be appropriate to help farmers, so long as they do not undermine farmers’ incentive to use commercial fertilizer and do improve household income in the long run.

Thank you!

Liu and Myer's output index (2009)

$$\mathrm{Y}_{\mathrm{ijt}} = \sum_{n} \frac{Y_{is} P_{s}}{P_{m}}$$

Soil group number and criteria (number of villages)	Number of villages by soil classification	Number of villages by agro-ecological zone
1 Volcanic landform: Regosols and some Podzols (25)	Podzols: 2 Regosols: 23	High Potential Maize Zone: 9 Central Highlands: 16
2 High humus or highly productive: Phaeozems, Luvisols, Greyzems, Cambisols (21)	Cambisols: 4 Phaeozems: 6 Luvisols, 10 Greyzems: 1	Eastern Lowlands: 1 Western Transitional: 1 High Potential Maize Zone: 11 Western Highlands: 2 Central Highlands: 3 Marginal Rain Shadow: 3
3 Rankers with more sand (25)	Rankers: 25	Coastal Lowlands: 4 Eastern Lowlands: 11 Western Lowlands: 2 Western Transitional: 4 High Potential Maize Zone: 1 Western Highlands: 3
4 Rankers with less sand (20)	Rankers: 20	Western Lowlands: 1 Western Transitional: 6 High Potential Maize Zone: 7 Western Highlands: 5 Central Highlands: 1