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Incentivizing (Un)sustainable Intensification? Evidence from Zambia's Input Subsidy Program

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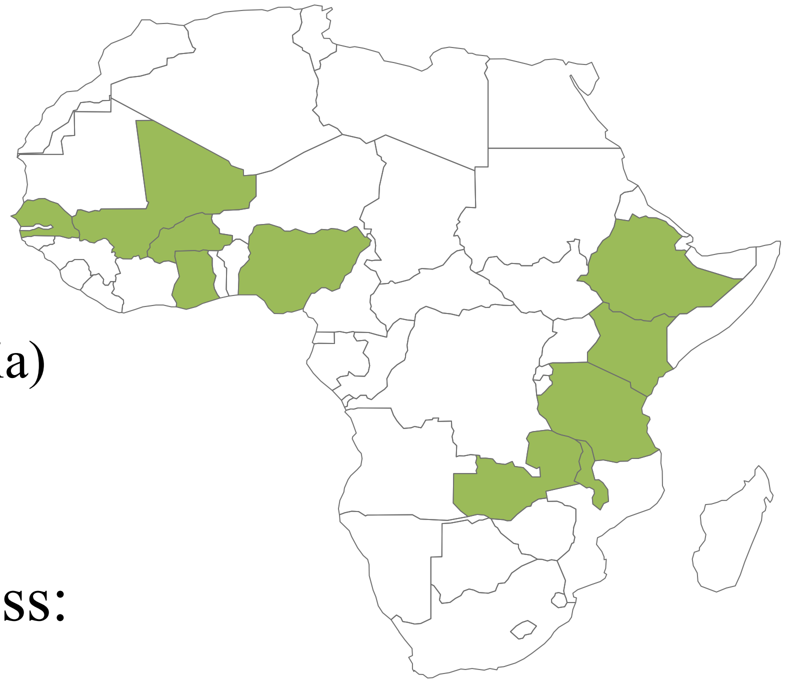
Overview of Input Subsidy Programs (ISPs)

- Spending on ISPs has topped **$1 billion/year** in 10 countries

- Fairly low yield gains and value:
  - 1.88 kg of maize for 1kg fertilizer (Zambia)
  - Benefit Cost Ratio = 0.92

- We highlight two constraints on success:
  - **Poor soil quality**
  - **Soil degradation**



Source: Jayne & Rashid (2013), Jayne et al. (2015)

Soil Fertility Management (SFM)

- Fertilizer subsidies likely change farmer incentives and willingness to adopt SFM practices contributing to **sustainable intensification**

- Examples:
  1. Intercropping
  2. Crop Rotation
  3. Fallowing
  4. Animal Manure
  5. Agroforestry

Predicting the Effects of ISPs

- When SFM and inorganic fertilizer are viewed as **complements** we expect crowding-in
  - Decrease the relative price of fertilizer
  - Farmers can re-optimize production (Beaman et al. 2013)

- If SFM and inorganic fertilizer are viewed as **substitutes**, we expect crowding out (Tittonell and Giller 2013)
  - Household resource constraints matter
  - Vicious cycle of further soil degradation

Main Research Question

- **Do fertilizer subsidies incentivize or disincentivize the use of other SFM practices?**
  - Panel data from Zambia
  - Robust literature on fertilizer subsidies in SSA but only 3 other studies on this dimension
    - Holden & Lunduka (2012) – Malawi
    - Vondolia et al. (2012) - Ghana
    - Koppmair et al. (2016) - Malawi

Zambia's fertilizer subsidy programs

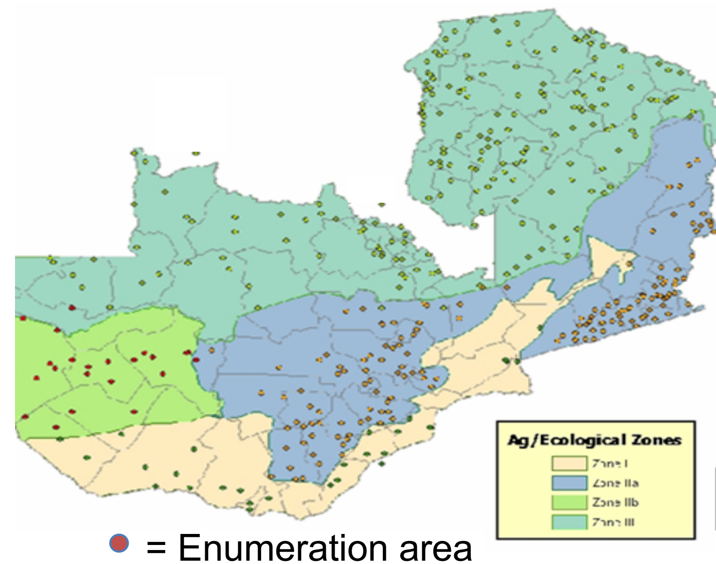
- **Fertilizer Support Program (FSP, 2002/03-2008/09)**
  - Selected beneficiaries supposed to get **400 kg inorganic fertilizer, 20 kg hybrid maize seed** but highly variable
  - Apply through co-op, approved by extension officer
  - Results based on 2002/03 and 2006/07 ag. seasons

	2002/03	2006/07
% of SH HHs participating	9%	11%
Subsidy rate	50%	60%

- **Farmer Input Support Program (2009/10-present)**

Data

- **"Supplemental Survey"** – nationally representative
- **3-wave panel**: 1999/2000, 2002/03, and 2006/07
- **4,286 SH HHs** in all 3
- Info on **FSP participation, use of SFM practices**, farm & HH characteristics, etc.
- Combine with geospatial data on **rainfall, soils, slope**, etc.



SFM practices analyzed

- **Fallowing**
- **Animal manure**
- **Intercropping**
- **Continuous Maize**
- **Maize Monocropping**

- **Dependent Variable:**
  - Yes/No
  - Area under practice
  - Share of area

Nonseparable Agricultural Household Model

$$\underset{c_t, f_t^c, f_t^s, L_t^a, m_t, \phi_{it}}{\text{maximize}} \quad U(c_t; z_t^c)$$

- Household maximizes utility by choosing:
  - Vector of Consumption Goods c_t
  - Purchased Fertilizer f_t^c
  - Subsidized Fertilizer f_t^s
  - Agricultural Labor L_t^a
  - Organic Fertilizer m_t
  - SFM practice ϕ_{it}

Selected Key Constraints

- SFM practice specific production function

$$y_{it} = y_{it}(x_t, f_t, m_t, \phi_{it}, L_t^a, f_t m_t \phi_{it}; \bar{A}, z_t^q)$$

- Missing market for organic fertilizer

$$m_t \leq h(\text{Liv})$$

- FSP allocation policies

$$f_t^s \leq \bar{f}^s(z_t^c, z_t^q)$$

- Soil fertility transition equation

$$x_{t+1} = g(x_t, f_t, m_t, \phi_{it})$$

Nonseparable AHM Solution

Solving the static model, we get the following equation:

$$\phi_{it}^{*} = \phi(x_t, f_t, m_t, L_t^a, p_t, w_t^f, s_t, w_t^l, \lambda, \mu, \eta, \bar{A}, z_t^c, z_t^q)$$

Dynamic solution would differ for forward-looking farmers

- Drives a wedge between the marginal revenue and the marginal factor cost of adopting a given SFM practice
- Data intensive to estimate (e.g. Berazneva et al. 2014)

Empirical Model

$$P(SFM_{it} = 1 | FSP_{it}, \mathbf{A_{it}}, \mathbf{L_{it}}, \mathbf{p_{it}}, \mathbf{z_{it}}, \mathbf{m_{it}}, \mathbf{g_{it}}, \mathbf{d_t}, \mathbf{c_i}) =$$
$$\Phi(\beta_0 + \beta_1 FSP_{it} + \mathbf{A_{it}}\beta_2 + \mathbf{L_{it}}\beta_3 + \mathbf{p_{it}}\beta_4 + \mathbf{z_{it}}\beta_5 + \mathbf{m_{it}}\beta_6 + \mathbf{g_{it}}\beta_7 + \mathbf{d_t} + \mathbf{c_i})$$

SFM = 1 if HH adopts the practice

FSP = kg of FSP

A = Size of landholding

L = Labor availability/ Household composition

p = Variable input and expected output prices

z = Household characteristics

m = Market characteristics and access to information

g = Land quality and agro ecological conditions

Potential Endogeneity of Subsidized Fertilizer

- Farmers self-select into the FSP program
- Employ results of last presidential election in the HH's constituency district as an IV (F>10) for FSP fertilizer receipt (Mason and Jayne 2013)
- Leverage control function (CF) approach to test for endogeneity
  - **Fail to reject** the null hypothesis of exogeneity at the 5% level in all cases

Fallowing Results

SFM Practice		Estimator	APE * 200	Sig	Effect Size
General	=1 if used practice	CRE Probit	-0.031	***	-0.062
	Area (ha)	CRE Tobit	-0.086	***	-0.056
	Share	CRE Frac. Resp.	-0.017	***	-0.071
Improved	=1 if used practice	CRE Probit	-0.010	***	-0.164
	Area (ha)	CRE Tobit	-0.011		-0.187
	Share	CRE Frac. Resp.	-0.003		-0.311
Natural	=1 if used practice	CRE Probit	-0.024	**	-0.048
	Area (ha)	CRE Tobit	-0.077	***	-0.050
	Share	CRE Frac. Resp.	-0.015	**	-0.061

*, **, *** represent p-vals of ≤0.1, ≤0.05, ≤0.01, respectively

Intercropping Results

	SFM Practice	Estimator	APE * 200	Sig	Effect Size
General	=1 if used practice	CRE Probit	-0.017		-0.042
	Area (ha)	CRE Tobit	-0.015		-0.025
	Share	CRE Frac. Resp.	-0.007		-0.040
Legume	=1 if used practice	CRE Probit	-0.006		-0.021
	Area (ha)	CRE Tobit	-0.005		-0.009
	Share	CRE Frac. Resp.	-0.003		-0.022

*, **, *** represent p-vals of ≤0.1, ≤0.05, ≤0.01, respectively

Organic Fertilizer

SFM Practice		Estimator	APE * 200	Sig	Effect Size
Animal manure	=1 if used practice	CRE Probit	-0.001		-0.003
	Area (ha)	CRE Tobit	-0.007		-0.011
	Share	CRE Frac. Resp.	-0.003		-0.016

*, **, *** represent p-vals of ≤0.1, ≤0.05, ≤0.01, respectively

Low power: Low adoption

6.8% adoption across all households

80% of population don't own cattle

Continuous Maize & Maize Monocropping

	Practice	Estimator	APE * 200	Sig	Effect Size
Continuous	=1 if used practice	CRE Probit	0.017	*	0.034
	Area (ha)	CRE Tobit	0.047	*	0.053
	Share	CRE Frac. Resp.	0.008		0.021
Monocrop	=1 if used practice	CRE Probit	0.070	***	0.162
	Area (ha)	CRE Tobit	0.190	***	0.210
	Share	CRE Frac. Resp.	0.024	***	0.075

*, **, *** represent p-vals of ≤0.1, ≤0.05, ≤0.01, respectively

Assessing the Overall Effect

		Estimator	APE * 200	Sig	Effect Size
Number of Practices	Count of Practices (Fallow, Intercrop, Manure)	CRE Poisson	-0.04	*	-0.049

- Sustainable intensification may require adopting a combination of practices
- Think about how to combine or count SFM practices

Conclusions & Policy Implications

- **FSP** appears to have incentivized
  - Less fallowing
  - More continuous maize cultivation over time
  - More maize monocropping within a given year

- While the program marginally **raised maize yields**, it may have **incentivized unsustainable intensification**

- Making FISP **less maize-centric** and improving **R&D and extension on SFM** might ↓ these unintended consequences and ↑ returns to FISP