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**Assessing Complementarities Among Farm Machineries Through Farmers' Investment Behaviors Under An External Capital Injection – Implications on Agricultural Mechanization and Tractorization In Sub-Saharan Africa**

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## 1. Background issue

- Challenge in supporting sophisticated farm machineries (tractors) in developing countries like Nigeria**
  - Scale of required financial support, public sector capacity
- Low level of current farm mechanization**
  - Rare use of not only tractors but also draft animals
  - Potentially high demand for hand tools (hoe, cutlass)
- Literature indicating the role of less sophisticated farm tools**
  - Higher demand for **intermediate tools** (draft animals, processing machines) or **hand tools** (Mrema et al., 2008)
  - General patterns of mechanization (Rijk, 1999):
    - Hand tools => draft animals => mechanization of stationary operation (processing – milling machine) => motive operation (tractors)
    - => necessary pre-conditions for the adoptions of tractors:
      - Adoptions of intermediate tools (draft animals, stationary operation)
- Potentially complementary roles played by less sophisticated tools**
  - Access to draft animals or milling machines = process and transport large harvest from using tractors for land preparation
  - Individual farmers' ownership of hand tools = complement the use of draft animals or milling machines

## 2. Descriptive statistics

	Farmers who owned these tools in 2005				
	All	Hand tools	Draft animal	Milling machine	Tractor / power tiller
Age	42	42	42	40	46
Gender (% female)	29	23	9	26	25
% completed primary education	58	57	49	58	67
% completed secondary education	33	34	29	32	50
Household size	9	9	12	10	10
Household expenditure in 2005 (\$)	238	227	190	522	283
% rented in land in 2005	11	13	9	15	33
% received credit in 2005	12	12	13	10	13
% primary activity is cropping	55	68	73	47	88
% primary activity is non-farm activity	18	11	9	27	0

  

	Owned in 2005	Invested in 2006	Fadama II member (2006)			Root crop grower in 2005	Vegetable grower in 2005
			All	Dry savannah	Moist savannah		
Hand tools	59	13	18	19	20	14	21
Draft animal	11	4	9	17	6	1	9
Milling machine	4	3	7	5	11	6	2
Tractor / power tiller	1	0.3	1	1	1	1	1

## 3. Conceptual framework

**Utility maximization under liquidity constraint and production risk**

Max  $E\{U[\pi]\}$   
s.t.  $\pi = p \cdot f(x_1, x_2, \eta) - w_1 x_1 - w_2 x_2$   
 $w_1 x_1 + w_2 x_2 + \theta \leq T$

**Lagrangian:**  
 $L = E\{U[p \cdot f(x_1, x_2, \eta) - w_1 x_1 - w_2 x_2]\} + \lambda(T - w_1 x_1 - w_2 x_2 - \theta)$

**Demand for  $k$  ( $x_k$ ) satisfies**  
 $w_k / p \leq \{E[U(\pi)] \cdot E[\partial U / \partial x_k] + cov(U(\pi), \partial U / \partial x_k)\} / \{E[U(\pi)] + \lambda\} = \mu^k$   
(\*Inequality when liquidity constraint is binding)  
 $\mu^k$ : willingness to pay for additional  $k$  (standardized by  $p$ )

**Ownership of  $j$  => affects relationship between  $\mu^k$  and  $\mu^j$**

**Key factors** - Shape of production possibility frontier with respect to  $j$  and  $k$   
- Common inputs used for  $j$  and  $k$

	Explanation	Possible example
<b>Owning <math>j</math> (more <math>x_j</math>) increases <math>x_k</math> when there is <math>\Delta T</math> if</b>		
<b>Low <math>\partial f / \partial x_j</math></b>	- No scale of economy in $j$	Due to the lack of tractor ( $k$ ), harvest is small and milling machine ( $j$ ) is under-used => additional milling machine provides no return
<b>Large <math> cov[U, \partial f / \partial x_j] </math></b>	- Low depreciation rate of $j$ $j$ is risk increasing	
<b>High <math>\partial f / \partial x_k</math></b>	- $k$ and $j$ are complements	Tractor ( $k$ ) is more profitable if owning milling machine ( $j$ ) raises return from larger harvest
<b>Small <math> cov[U, \partial f / \partial x_k] </math></b>	- Investing into $k$ is not risky	
<b>Owning <math>j</math> (more <math>x_j</math>) decreases <math>x^k</math> when there is <math>\Delta T</math> if</b>		
<b>High <math>\partial f / \partial x_j</math></b>	- Scale of economy from $j$	Many farmers bring their harvests for milling for fee => additional milling machine ( $j$ ) provides additional return Owning milling machine mitigates the price risk for unprocessed crops
<b>Small <math> cov[U, \partial f / \partial x_j] </math></b>	- Depreciation of $j$ $j$ is risk decreasing	
<b>Low <math>\partial f / \partial x_k</math></b>	- $k$ and $j$ are substitutes	
<b>Large <math> cov[U, \partial f / \partial x_k] </math></b>	- Investment into $k$ is risky, requires learning, resources for risk mitigation	Allocating them for milling machine => Less such resources left for tractor ( $k$ ) => Return is lower / riskier from tractor

## Empirical specification

- First difference panel using data from 2005 and 2006
- GMM => farmers' self-selection into project participation

$$\begin{bmatrix} h_t \\ d_t \\ m_t \\ T_t \end{bmatrix} = \beta \cdot \Delta F_t + \Delta F_t \cdot \begin{bmatrix} \gamma_{HH} & \dots & \gamma_{HT} \\ \vdots & \ddots & \vdots \\ \gamma_{TH} & \dots & \gamma_{TT} \end{bmatrix} \cdot \begin{bmatrix} H_t \\ D_t \\ M_t \\ T_t \end{bmatrix} + \text{other} + \begin{bmatrix} \varepsilon_t^h \\ \varepsilon_t^d \\ \varepsilon_t^m \\ \varepsilon_t^T \end{bmatrix}$$

Endogenous due to self-selection ( $\Delta F_t$ ) => GMM

**Definitions:**  
 $h_t, d_t, m_t, T_t$  = 1 if a farmer  $i$  invested in 2006 into hand tools (machete / cutlass / hoe) ( $h_t$ ), draft animal (ox-plow / work bull) ( $d_t$ ), milling machine ( $m_t$ ), tractor / tractor-plow / power tiller ( $T_t$ )  
 $H_t, D_t, M_t, T_t$  = 1 if a farmer  $i$  owned in 2005 hand tools (machete / cutlass / hoe) ( $H_t$ ), draft animal (ox-plow / work bull) ( $D_t$ ), milling machine ( $M_t$ ), tractor / tractor-plow / power tiller ( $T_t$ )  
 $\Delta F_t$  = 1 if joined the Fadama II project in 2006 (prior to the investment)

**Excluded IVs:**  
 $\Delta E^*H_t$ : Eligibility to Fadama II \* owned hand tools in 2005 or not  
 $\Delta E^*O_t$ : Eligibility to Fadama II \* owned draft animal in 2005 or not  
 $\Delta E^*M_t$ : Eligibility to Fadama II \* owned milling machine in 2005 or not  
 $\Delta E^*T_t$ : Eligibility to Fadama II \* owned tractors / tractor-plow / power tiller in 2005 or not  
 $\Delta E^*Root\ crop_t$ : Eligibility to Fadama II \* grew rootcrops in 2005 or not  
 $\Delta E^*Vegetable_t$ : Eligibility to Fadama II \* grew vegetables in 2005 or not  
 $\Delta E^*Household\ expenditure_t$ : Eligibility to Fadama II \* total household expenditure in 2005  
 $\Delta E^*Dependency\ ratio_t$ : Eligibility to Fadama II \* dependency ratio

## 4. Empirical results and policy implications

	Key results by agro-ecological zones			
	Hand tools	Draft animals	Milling machine	Tractor / power tiller
<b>Dry-savannah</b>				
Fadama*H	-0.640***	-0.007	-0.032	-0.002
Fadama*D	-0.070	.181	-0.018	-0.005
Fadama*M	-0.050	-0.120**	.015	.013
Fadama*T	.025	-0.191	-0.019	.200***
<b>Moist-savannah</b>				
Fadama*H	-0.504***	-0.150***	.091	.025*
Fadama*D	.413**	.218**	.041	-0.015
Fadama*M	-.245	-.124*	-.045	-.009
Fadama*T	-.133	-.019	-.078	-.024
<b>Humid-forest</b>				
Fadama*H	-.520***	-.004	.024	.003
Fadama*D	-.117	.252***	-.074	-.053
Fadama*M	.088	-.002	.201***	.014
Fadama*T	.024	-.013	-.044	.047

### Summary of findings

- Ownership of less sophisticated farm machineries => **no positive effect on the investment into more sophisticated machineries**
- Farmers tend to continue investing in the same type of farm machineries
- Though we cannot say much about the mechanization patterns, we may say:
  - Farm mechanization may evolve along 1) hand tools => 2) draft animal => 3) stationary operation => 4) motive operation but **not at the individual farmer level**

### Implications of preliminary results

- Farmers prefer to invest in specific farm machineries**
  - Their aversion to risk for investing in other complementary farm machineries may be greater than the potential benefits
- Targeting of farmers is more important when supporting adoptions of particular farm machineries**
  - Program like Fadama II may be more appropriate as farmers have ranges of farm machineries to choose from
- Nigerian government's continued focus on tractorization makes some sense**
  - Supporting adoptions of supposedly complementary machineries do not encourage adoptions of tractors
  - Although supporting less sophisticated complementary machineries is more feasible, direct support for tractor adoptions should remain substantial

### Selected reference

Binswanger, H. and Pingali, P. (1988). Technological priorities for farming in Sub-Saharan Africa. *The World Bank Observer* 3(1), 81-98.

Mrema C, Baker D., and Kahan D. (2008). *Agricultural mechanization in sub-Saharan Africa: time for a new look*. FAO, Rome.

Nkonya, E. et al. (2008). *From the ground up: Impacts of a pro-poor community-driven development project in Nigeria*. IFPRI Discussion Paper 00756. Washington, DC.

Pingali, P. (2007). Agricultural mechanization: Adoption patterns and economic impact. *Handbook of Agricultural Economics* 3, 2779-2805

Rijk AG. 1999. Agricultural mechanization strategy. *Plant Production Engineering*: 536-553. Available at [http://www.unapcaem.org/publication/CIGR\\_APCAEM\\_Website.pdf](http://www.unapcaem.org/publication/CIGR_APCAEM_Website.pdf).

Takeshima, H. and F. Yamauchi. 2010. Market and climatic risks and farmers' investment in productive assets under Second Fadama Development Project in Nigeria. *IFPRI Discussion Paper* 01033.

Michael Tomz, Gary King, and Langche Zeng. 1999. RELOGIT: Rare Events Logistic Regression, Version 1.1. Cambridge, MA: Harvard University, October 1, <http://gking.harvard.edu>.

Gary King and Langche Zeng. 1999b. "Estimating Absolute, Relative, and Attributable Risks in Case-Control Studies." Department of Government, Harvard University, available from <http://Gking.harvard.edu>.

Wooldridge JM. 2002. *Econometric Analysis of Cross Section and Panel Data*. MIT Press.

