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

Hiroyuki Takeshima
International Food Policy Research Institute, H.takeshima@cgiar.org

Sheu Salau
International Food Policy Research Institute

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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

Hiroyuki Takeshima[1], Sheu Salau[1]
[1]International Food Policy Research Institute (IFPRI), Nigeria office (H.takeshima@cgiar.org)

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	Humid forest		
Hand tools	59	13	18	19	20	14	17	21
Draft animal	11	4	9	17	6	1	2	9
Milling machine	4	3	7	5	11	6	7	2
Tractor / power tiller	1	0.3	1	1	1	1	1	1

3. Conceptual framework

Utility maximization under liquidity constraint and production risk

Max $E\{U[\pi]\}$

s.t. $\pi = p \cdot f(x_k, x_j, \eta) - w_k x_k - w_j x_j$

$w_k x_k + w_j x_j + \theta \le T$

Lagrangian:

$L = E\{U[p \cdot f(x_k, x_j, \varepsilon) - w_k x_k - w_j x_j]\} + \lambda(T - w_k x_k - w_j x_j - \theta)$

Demand for k (x_k*) satisfies

$w_k / p \le \{E[U'(\pi)] \cdot E[\partial f / \partial x_k] + cov[U'(\pi), \partial f / \partial x_k]\} / \{E[U'(\pi)] + \lambda\} = \mu^k$

(*Inequality when liquidity constraint is binding)

μ^k: willingness to pay for additional k (standardized by p)

In perfect market: $\mu^k = \mu^j$

In imperfect market: $\mu^k > \mu^j$ or $\mu^k < \mu^j$

External capital injection ΔT
$\Rightarrow \lambda \downarrow$
$\Rightarrow$ Farmer changes x_k and x_j until $\mu^k = \mu^j$

	Definitions
π	Profit
p	Output price
f	Production function
x_j, x_k	Quantities of inputs j and k
η	Production risk
w_j, w_k	Prices of inputs j and k
T	Total liquidity asset
θ	Other cash requirements
λ	Lagrange multiplier (liquidity constraint)

Ownership of j => affects relationship between μ^k and μ^j

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

Owning j (more x_j) increases x_k when there is ΔT if

	Explanation	Possible example
Low $\partial f / \partial x_j$ **Large** $\lvert cov[U', \partial f / \partial x_j] \rvert$	- No scale of economy in j - Low depreciation rate of j - j is risk increasing	Due to the lack of **tractor** (k), harvest is small and **milling machine** (j) is under-used => additional **milling machine** provides no return
High $\partial f / \partial x_k$ **Small** $\lvert cov[U', \partial f / \partial x_k] \rvert$	- k and j are complements - Investing into k is not risky	**Tractor** (k) is more profitable if owning **milling machine** (j) raises return from larger harvest

Owning j (more x_j) decreases x^k when there is ΔT if

	Explanation	Possible example
High $\partial f / \partial x_j$ **Small** $\lvert cov[U', \partial f / \partial x_j] \rvert$	- Scale of economy from j - Depreciation of j - j is risk decreasing	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
Low $\partial f / \partial x_k$ **Large** $\lvert cov[U', \partial f / \partial x_k] \rvert$	- k and j are substitutes - Investment into k is risky, requires learning, resources for risk mitigation	Owning **milling machine** (j) requires electricity, cash for operation / maintenance. Allocating them for **milling machine** => Less such resources left for **tractor** (k) => Return is lower / riskier from **tractor**

4. Empirical results and policy implications

Empirical specification

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

$$\begin{bmatrix} h_i \\ d_i \\ m_i \\ t_i \end{bmatrix} = \beta \cdot \Delta F_i + \Delta F_i \cdot \begin{bmatrix} \gamma_{HH} & \cdots & \gamma_{HT} \\ \vdots & \ddots & \vdots \\ \gamma_{TH} & \cdots & \gamma_{TT} \end{bmatrix} \cdot \begin{bmatrix} H_i \\ D_i \\ M_i \\ T_i \end{bmatrix} + \text{other} + \begin{bmatrix} \varepsilon_i^h \\ \varepsilon_i^d \\ \varepsilon_i^m \\ \varepsilon_i^t \end{bmatrix}$$

Endogenous due to self-selection (ΔF_{it}) => GMM

	Definitions	
h_i, d_i, m_i, t_i	= 1 if a farmer i invested in 2006 into	**hand tools (machete / cutlass / hoe) (h_i)** **draft animal (ox-plow / work bull) (d_i)** **milling machine (m_i)** **tractor / tractor-plow / power tiller (t_i)**
H_i, D_i, M_i, T_i	= 1 if a farmer i owned in 2005	**hand tools (machete / cutlass / hoe) (h_i)** **draft animal (ox-plow / work bull) (d_i)** **milling machine (m_i)** **tractor / tractor-plow / power tiller (t_i)**
ΔF_i	= 1 if joined the Fadama II project in 2006 (prior to the investment)	

Excluded IVs	
$\Delta E_i{}^*H_i$	**Eligibility** to Fadama II * owned **hand tools** in 2005 or not
$\Delta E_i{}^*O_i$	**Eligibility** to Fadama II * owned **draft animal** in 2005 or not
$\Delta E_i{}^*M_i$	**Eligibility** to Fadama II * owned **milling machine** in 2005 or not
$\Delta E_i{}^*T_i$	**Eligibility** to Fadama II * owned **tractors / tractor-plow / power tiller** in 2005 or not
$\Delta E_i{}^*Root\ crop_i$	**Eligibility** to Fadama II * grew **rootcrops** in 2005 or not
$\Delta E_i{}^*Vegetable_i$	**Eligibility** to Fadama II * grew **vegetables** in 2005 or not
$\Delta E_i{}^*Household\ expenditure_i$	**Eligibility** to Fadama II * total household expenditure in 2005
$\Delta E_i{}^*Dependency\ ratio_i$	**Eligibility** to Fadama II * dependency ratio

Estimation results (all agro-ecological zones combined with dummy for agro-ecological zones)

	GMM				Rare events Logit
	Hand tools	Draft animals	Milling machine	Tractor / power tiller	Tractor / power tiller
Fadama II participation (yes =1)	.509***	.076	.041	.001	
Fadama*H	-.535***	-.052	-.033*	.011	.011*
Fadama*D	-.000	.200***	-.035*	-.012	.004
Fadama*M	-.136**	-.084***	.082*	-.006	
Fadama*T	-.108	-.105	-.047*	.100***	.004*
Fadama*Root crop	.157***	-.043**	.108***	.012	
Fadama*Vegetable	.204***	.168***	-.014	.014*	
Eligible (yes = 1)	-.135**	-.072**	-.023	.003	
Eligible*rented in land in 2005	.052**	-.011	.016	-.006	
Eligible*age	.000	.001	.001*	.000	
Eligible*gender	-.114***	-.039*	.018	.005	
Eligible*household size	-.005***	-.000	.000	.000	
Eligible*primary education	.018	.001	.005	.002	
Eligible*secondary education	-.032	.013	-.002	.003	
Eligible*dry savannah	-.100**	.115***	-.046***	-.004	
Eligible*moist savannah	.043	.061***	-.026	.006	
Eligible*storage space	.140	-.016	-.022**	.000	
Eligible*credit	-.052	.035	.033*	.006	
Eligible*state 3	.077**	.021	.055***	.015**	
Eligible*state 4	-.056	.012	-.049**	-.008	
Eligible*state 5	.184***	-.112***	.024**	-.001	
Eligible*state 6	.130***	-.053*	.013***	-.001	
Eligible*state 7	-.044	-.026	.085***	-.014**	
Eligible*state 8	-.074	-.008	-.053***	.019***	
Eligible*state 12	-.033	-.016	.022	-.008	
Intercept	.124***	.007**	.011***	.000	
p-value (overall fit)	.000	.000	.000	.000	
p-value (weak identification)	.001	.001	.000	.000	
p-value (overidentification)	.300	.803	.796	.821	
Observation	2822	2822	2822	2822	2822

***: 1% **: 5% *: 10%

Note: Rare events Logit – marginal effect at the mean of all other variables

Key results by agro-ecological zones

	Hand tools	Draft animals	Milling machine	Tractor / power tiller
Dry-savannah				
Fadama*H	-.640***	-.007	-.032	-.002
Fadama*D	-.070	.181	-.018	-.005
Fadama*M	-.050	-.120**	.015	.013
Fadama*T	.025	-.191	-.019	.200***
Moist-savannah				
Fadama*H	-.504***	-.150***	.091	.025*
Fadama*D	.413**	.218**	.041	-.015
Fadama*M	-.245	-.124*	-.045	-.009
Fadama*T	-.133	-.019	-.078	-.024
Humid-forest				
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

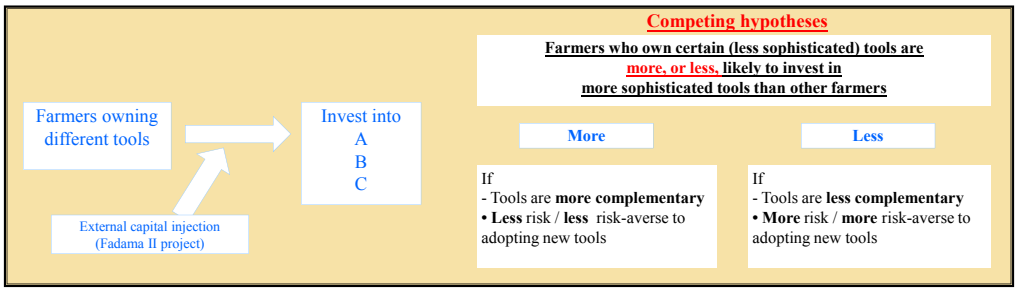
- **Ownership of less sophisticated farm machineries => no positive effect on the investment into more sophisticated machineries**
- **Farmers tend to continue investing in the same type of farm machineries**
- **Though we cannot say much about the mechanization patterns, we may say;**
  - Farm mechanization 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

1. **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
2. **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
3. **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 G, 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.
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. 1999a. "Logistic Regression in Rare Events Data," Department of Government, Harvard University, 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.


Competing hypotheses
Farmers who own certain (less sophisticated) tools are more, or less, likely to invest in more sophisticated tools than other farmers
Farmers owning different tools
Invest into
A
B
C
External capital injection (Fadama II project)
More
Less
If
- Tools are more complementary
• Less risk / less risk-averse to adopting new tools
If
- Tools are less complementary
• More risk / more risk-averse to adopting new tools