INTERNATIONAL FOOD
POLICY RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty
Supported by the CGIAR

IFPRI Discussion Paper 01033

November 2010

Market and Climatic Risks and Farmers' Investment in Productive Assets under the Second Fadama Development Project in Nigeria

Hiroyuki Takeshima

Futoshi Yamauchi

Development Strategy and Governance Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975. IFPRI is one of 15 agricultural research centers that receive principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR).

PARTNERS AND CONTRIBUTORS

IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Denmark, Finland, France, Germany, India, Ireland, Italy, Japan, the Netherlands, Norway, the Philippines, South Africa, Sweden, Switzerland, the United Kingdom, the United States, and the World Bank.

AUTHORS

Hiroyuki Takeshima, International Food Policy Research Institute
Post Doctoral Fellow, Development Strategy and Governance Division
h.takeshima@cgiar.org

Futoshi Yamauchi, International Food Policy Research Institute
Senior Research Fellow, Poverty, Health, and Nutrition Division
f.yamauchi@cgiar.org

Notices

[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at http://www.ifpri.org/publications/results/taxonomy%3A468.

[2] IFPRI Discussion Papers contain preliminary material and research results. They have been peer reviewed, but have not been subject to a formal external review via IFPRI's Publications Review Committee. They are circulated in order to stimulate discussion and critical comment; any opinions expressed are those of the author(s) and do not necessarily reflect the policies or opinions of IFPRI.

Contents

List of Tables

ABSTRACT

The majority of African farmers lack the means to mitigate the impact of risks such as those associated with rainfall and commodity prices. Because most farmers in Sub-Saharan Africa are risk-averse, they may be willing to invest in productive assets that can mitigate the impacts of such risks if their capital constraints are relaxed through external financial assistance. We test this hypothesis using panel data on Nigerian farmers' investment behaviors collected during the Second National Fadama Development Program (Fadama II), which provided financial assistance to farmers in obtaining various productive assets, as well as historical data on rainfall and white *gari* price in various locations in Nigeria. The results support the hypothesis. Under the Fadama II, farmers facing higher rainfall risk (coefficient of variation in annual rainfall) were more likely to invest in irrigation pumps that can mitigate the impact of rainfall risk, and those facing higher risks on white *gari* price were more likely to invest in milling machines that enable them to process cassava into flour instead of *gari*.

Keywords: poverty trap, rainfall risk, price risk, irrigation pump, milling machine, risk aversion

ACKNOWLEDGMENTS

We would like to thank Ephraim Nkonya and Edward Kato for providing Fadama II Dataset and advice, the Nigerian Meteorological Agency and the National Bureau of Statistics of Nigeria for sharing the historical data of rainfall and retail prices, and Sheu Salau for making the above data accessible for us. We are also grateful to Yanyan Liu, Margaret McMillan, participants at the IFPRI-Nigeria brown bag seminar and anonymous reviewers for their useful comments and suggestions. Of course, any remaining errors are ours.

1. BACKGROUND AND RESEARCH QUESTION

The majority of farmers in Nigeria, as in the rest of Sub-Sahara Africa, are vulnerable to various types of market-related and climatic risks. Although farmers mobilize various resources to partly insure themselves against such risks, they are often resource poor and lack the capacity for sufficient insurance. Productive assets may play dual roles in an environment susceptible to risks. They not only increase the productivity or profitability, but they also potentially shield farmers from certain risks. For example, an irrigation pump allows farmers to overcome erratic rainfall and a milling machine allows them to sell processed cassava (such as cassava flour) instead of cassava tuber or *gari* (other popular cassava products processed without using a milling machine).[1] Risk-averse farmers in developing countries like Nigeria may be more willing to invest in such productive assets if external financial support is available. Farmers facing higher variation in rainfall may be more willing to invest in irrigation pumps. Farmers observing more variation in *gari* price may be more willing to invest in milling machines to start processing cassava into flour instead of *gari*.

Public support programs have been implemented in a variety of forms to help farmers invest in productive assets that can partly mitigate their risks. In Nigeria, the Second Fadama Development Program (Fadama II) was implemented from 2004 through 2006, leading to new, large-scale investment by farmers in many productive assets, including irrigation pumps and milling machines (Nkonya et al. 2008). How farmers benefit from public support programs like Fadama II depends not only on how liquidity-constrained the beneficiary farmers are or how much return the investment in productive assets brings on average, but also how such investments can mitigate the risks the farmers face. The impacts of these programs are often evaluated by subsequent changes in farmers' incomes. The evaluation of actual benefits of such programs, however, may also need to consider how they improve farmers' capacity by mitigating the effects of risks they are exposed to. Though the evaluation of actual benefits from such improvement in risk-coping capacity is not straightforward, we can gain useful insights from whether the farmers' investment decisions under programs like Fadama II depend on the level of the risks they are exposed to.

This paper empirically examines whether farmers' investments in irrigation pumps and milling machines during the Fadama II program were affected by climatic and market risks. More specifically, this paper examines whether farmers were more likely to invest in irrigation pumps and milling machines under Fadama II if they were located in the regions with higher variations in annual rainfall and white *gari* price. Both the linear probability model (LPM) in two-stage least squares (2SLS) specification and stratified propensity score matching (PSM) method are used to correct the potential self-selection by farmers to participate in the Fadama II program. Our results support the hypothese that higher rainfall risk led to more investment in irrigation pumps, and higher white *gari* price risk led to more investment in milling machines.

This paper also provides evidence that potential benefits from public interventions aiming to support their acquisition of productive assets depend on the risks farmers are facing, and potentially on the incompleteness of markets such as missing insurance market. Precautionary or buffer stock motives in asset accumulation is well known in the context of developing countries where the market system does not provide means to insure against a variety of risks. Credit market is often imperfect too. The results in this paper indicate that public programs like Fadama II can potentially help farmers to overcome such market failures.

---

[1] In Nigeria, cassava is processed into various products, including gari (a granular product) and flour. Although gari is sometimes called "fermented cassava flour" (Onweluzo and Eilittä 2003) and cassava flour is sometimes called "unfermented cassava flour," gari and unfermented cassava flour are made in quite different ways, including the use or nonuse of a milling machine. While a milling machine is used to make unfermented cassava flour from dried cassava chips, it is not used to make gari from cassava in Nigeria (Taiwo 2006).

Unfermented cassava flour is therefore a substitute product for gari for cassava producers in Nigeria. A higher price risk for gari is therefore expected to make farmers invest in milling machines to process cassava into unfermented flour instead of gari as a safer option.

In addition, by analyzing how farmers' investment responds to the relaxation of liquidity constraints, we have deeper insights about broader issues of poverty traps. The fact that farmers invest in productive assets based on risk mitigation rather than maximization of expected profit is an indication of potential poverty traps wherein poor farmers remain poor due to their lack of sufficient risk management capacity (Barrett and Carter 2006).

The paper is organized as follows: The next section lays out our conceptual framework and describes key hypotheses. Section 3 discusses empirical strategy. We use instrumental variable and propensity score matching estimation. Data and policy intervention used in our analysis are described in Section 4. Section 5 reports our empirical results. Section 6 concludes.

2. CONCEPTUAL FRAMEWORK

Utility maximization problem for a farmer can be expressed as the following:

$$\max_{P_t, M_t, c_{kt}} E_t \sum_{t=1}^{\infty} \delta^t U(c_{kt}; z_t) \tag{1}$$

subject to

$$\begin{aligned} &\pi_{ft} s_{ft} + \pi_{gt} s_{gt} + \pi_{ct} s_{ct} + \Pi_t' S_t + T_t + W_t \\ &- P_t w_{pt}(1 - F \cdot f_p) - M_t w_{mt}(1 - F \cdot f_m) - \sum N_t w_{nt}(1 - F \cdot f_n) \geq 0 \quad \forall t = 0,\ldots,\infty \end{aligned} \tag{2}$$

$$P_t w_{pt} f_p + M_t w_{mt} f_m + \sum N_t w_{nt} f_n \leq f^* \qquad \text{if } F = 1 \qquad \forall t = 0,\ldots,\infty \tag{3}$$

$$\begin{aligned} &W_{t+1} = W_t + \pi_{ft} s_{ft} + \pi_{gt} s_{gt} + \pi_{ct} s_{ct} + \Pi_t' S_t + T_t \\ &- P_t w_{pt}(1 - F \cdot f_p) - M_t w_{mt}(1 - F \cdot f_m) - \sum N_t w_{nt}(1 - F \cdot f_n) \geq 0 \end{aligned} \tag{4}$$

$$q_{kt} - x_{kt} + A_{kt} - s_{kt} - c_{kt} \geq 0 \qquad \text{for all } k = 1 \ldots k;\ t = 0, \ldots, \infty \tag{5}$$

$$G(q_t, x_t, P_t, M_t, r_t; \psi_t) = 0 \qquad \text{for all } k = 1 \ldots k;\ t = 0, \ldots, \infty \tag{6}$$

$$r_t \sim \text{i.i.d}\ (\mu_r, \sigma_r) \text{ for all } t = 0, \ldots, \infty, \text{ with the level of risk measured as } \theta_r = \sigma_r / \mu_r \tag{7}$$

$$\pi_{gt} \sim \text{i.i.d}\ (\mu_g, \sigma_g) \text{ for all } t = 0, \ldots, \infty, \text{ with the level of risk measured as } \theta_g = \sigma_g / \mu_g \tag{8}$$

$$c_{kt}, q_{kt}, x_{kt} \geq 0 \quad \text{for all } k = 1 \ldots k;\ t = 0, \ldots, \infty, \tag{9}$$

in which farmer's utility is a function of consumption of goods k at t (c_{kt}) and other factors z_t summed across all the period from $t = 0$ to $t = \infty$ with discount factor δ. At t, a farmer chooses whether to invest in an irrigation pump ($P_t = 1$ if yes, 0 otherwise) and a milling machine ($M_t = 1$ if yes, 0 otherwise) and c_{kt} to maximize his utility. The budget constraint (2) states that, at each period t, the sum of net revenue minus net sale of cassava flour (s_{ft}) times cassava flour price (π_{ft}), net revenue for *gari* ($\pi_{gt}\, s_{gt}$), cassava tuber ($\pi_{ct} s_{ct}$), and the sum of net revenue for all the other commodities ($\Pi_t' S_t$ in which Π_t and S_t are a vector of other commodities prices and net sales, respectively), income from all other sources (T_t), and non-productive liquid assets at the beginning of period (W_t) must cover the cost farmers actually pay for the irrigation pump, milling machine, and other productive assets. The cost farmers actually pay for productive asset n (irrigation pump and milling machine are denoted p and m, respectively) that is the true price of asset w_{nt} minus the portion covered by Fadama II financial assistance (subsidy of $100 f_n$%) if the farmer is a Fadama II member ($F = 1$ if member, 0 if not) and if the farmer buys that asset ($N_t = 1$ if they buy, 0 if not). Therefore, in the instance of an irrigation pump, farmers pay $w_{pt}(1 - F \cdot f_p)$ while the remaining $w_{pt} F \cdot f_p$ is covered by the Fadama II financial assistance. For each farmer, the amount of total assistance from the Fadama II program is fixed at level *f**(constraint (3).[2] Equation (4) states that the beginning-period non-productive asset level at $t + 1$ (W_{t+1}) is the budget balance of t expressed as (2).

Equation (5) states that, at each t, the consumption of goods k (c_{kt}) cannot be greater than the sum of production (q_{kt}) and the initial endowment of k (A_{kt}) net the quantity used as inputs (x_{kt}) and net sales. Equation (6) states that the production of goods k (q_{kt}) is determined by the production technology defined in $G(\cdot)$, which states the relationship between production; input quantity; whether the farmer has an irrigation pump, milling machine, both, or neither; other determinants (ψ_t); and the rainfall level (r_t). The rainfall is assumed to fluctuate randomly around its mean (μ_r) with standard deviation (σ_r) (Equation (7)). Similarly, the price of cassava *gari* (π_{gt}) is assumed to fluctuate randomly around its mean (μ_g) with standard deviation (σ_g) (Equation [8]). The farmer perceives the levels of risk associated with rainfall and *gari* price by their respective coefficients of variations (θ_r and θ_g).[3] In our model, due to the limitation in data, only the inter-state variation in θ_r and θ_g are incorporated, and farmers in the same state are assumed to face the same levels of risk. For simplicity, we assume that the irrigation pump makes the farmer completely free from rainfall risk, and cassava flour price is fixed so that the milling machine makes a farmer completely free from *gari* price risk.

We now see how risk-averse farmers facing risks in rainfall or *gari* price may benefit from being able to invest in productive assets such as an irrigation pump and milling machine that can mitigate the impact of such risks. We specifically focus on the relationship between farmers' utility and the changes in θ_r and θ_g.

Modifying Rosenzweig and Wolpin (1993), the expected indirect utility function for a farmer at time t (V_t) can be expressed as

$$\begin{aligned} &E\big[V_t(z_t, T_t, W_t, A_{kt}, F, f_p, f_m, f_n, f^*, w_{pt}, w_{mt}, w_{nt}, \pi_{gt}, \pi_{ft}, \pi_{ct}, \Pi'_t, \psi_t, r_t, \mu_g, \sigma_g, \mu_r, \sigma \\ &= \max_{P_t, M_t, c_{kt}} \{ \iint U(c_{kt}; z_t) dH(r_t) dH(\pi_{gt}) + \delta \cdot \iint V_{t+1}(z_{t+1}, T_{t+1}, W_{t+1}, F, f_p, f_m, f_n, f^*, \\ &\qquad P_t, M_t, N_t, w_{p,t+1}, w_{m,t+1}, w_{n,t+1}, \\ &\qquad \pi_{g,t+1}, \pi_{f,t+1}, \pi_{c,t+1}, \Pi'_{t+1}, \psi_{t+1}, r_{t+1}) dH(r_{t+1}) dH(\pi_{g,t+1}) \} \end{aligned} \tag{10}$$

in which the expected operator is taken over the distribution function $H(\cdot)$ of rainfall and *gari* price. For simplicity, the distributions of rainfall and *gari* price are assumed independent of each other.

For a risk-averse farmer, we expect to have $\frac{\partial^2 V_t(\cdot)}{\partial (r)^2} < 0$ and $\frac{\partial^2 V_t(\cdot)}{\partial (\pi_g)^2} < 0$, meaning that the indirect utility function V is concave in rainfall and *gari* price. Then, under the Fadama II project, we have

$$\frac{\partial E[V_t \mid P_t = 0, F = 1]}{\partial \theta_r} < 0 \text{ and } \frac{\partial E[V_t \mid M_t = 0, F = 1]}{\partial \theta_g} < 0 \quad , \tag{11}$$

in which $E[V_t|P_t = 0, F=1]$ is the expected utility at time t of a farmer who is a Fadama II beneficiary but does not invest in irrigation pump, measured by expression (10), while $E[V_t|M_t = 0, F=1]$ is for a Fadama II beneficiary not investing in milling machine. Condition (11) says that in the absence of an irrigation pump a higher risk in rainfall lowers the farmer's expected utility, and in the absence of a milling machine a higher risk in *gari* price lowers the farmer's expected utility. On the other hand, we have

[2] The Fadama membership subsidy rates remain unchanged after $t = 1$, and therefore the subscript t is dropped.

[3] The distribution of *gari* price and rainfall are assumed constant over time t.

$$\frac{\partial E[V_t \mid P_t = 1, F = 1]}{\partial \theta_r} = 0 \text{ and } \frac{\partial E[V_t \mid M_t = 1, F = 1]}{\partial \theta_g} = 0 \tag{12}$$

meaning that, with an irrigation pump and a milling machine, the farmer's expected utility is unaffected by the increase in corresponding risks.

Conditions (11) and (12) together indicate

$$\frac{\partial \{E[V_t \mid P_t = 1, F = 1] - E[V_t \mid P_t = 0, F = 1]\}}{\partial \theta_r} > 0 \tag{13}$$

and

$$\frac{\partial \{E[V_t \mid M_t = 1, F = 1] - E[V_t \mid M_t = 0, F = 1]\}}{\partial \theta_g} > 0 \tag{14}$$

,

which say that the increase in expected utility from an investment in an irrigation pump and a milling machine is greater when rainfall risk and *gari* price risk are higher.

Under Fadama II, farmers' reservation benefit is from investment in other productive assets n, $E[V_t(\cdot|F = 1) \mid N_t = 1] - E[V_t(\cdot|F = 1) \mid N_t = 0)]$. Assuming that other productive assets do not mitigate the effect of rainfall risk and *gari* price risk, we have

$$\frac{\partial \{E[V_t \mid N_t = 1, F = 1] - E[V_t \mid N_t = 0, F = 1]\}}{\partial \theta_r} = 0 \tag{15}$$

and

$$\frac{\partial \{E[V_t \mid N_t = 1, F = 1] - E[V_t \mid N_t = 0, F = 1]\}}{\partial \theta_g} = 0 \tag{16}$$

.

Since only a fixed amount of financial assistance f^* can be received for the investment in productive assets, farmers under the Fadama II program invest in an irrigation pump before investing other productive assets if

$$\begin{aligned} E[V_t \mid P_t = 1, F = 1] - E[V_t \mid P_t = 0, F = 1] > \\ E[V_t \mid N_t = 1, F = 1] - E[V_t \mid N_t = 0, F = 1] \end{aligned} \tag{17}$$

and invest in a milling machine rather than other productive assets if

$$\begin{aligned} E[V_t \mid M_t = 1, F = 1] - E[V_t \mid M_t = 0, F = 1] > \\ E[V_t \mid N_t = 1, F = 1] - E[V_t \mid N_t = 0, F = 1]. \end{aligned} \tag{18}$$

Conditions (14) through (17) lead to the following expressions:

$$\partial \{\text{Probability}[(17) \text{ is true}]\} / \partial \theta_r > 0, \text{ or } \frac{\partial [\Pr(P_t = 1 \mid F = 1)]}{\partial \theta_r} > 0 \tag{19}$$

$$\partial\{\text{Probability}[(18)\text{ is true}]\} \,/\, \partial\,\theta_g > 0,\ \text{ or }\ \frac{\partial\left[\Pr(M_t = 1 \mid F = 1)\right]}{\partial\theta_g} > 0 \qquad (20)$$

A higher risk in rainfall leads to a higher probability of farmers' investing in an irrigation pump and a higher risk in *gari* price leads to a higher probability of farmers' investing in a milling machine. The two hypotheses tested in this study are that

Hypothesis 1: The change of likelihood of a farmer's investing in an irrigation pump following a capital injection like that of Fadama II is more positive in an environment with higher rainfall risks. (21)

Hypothesis 2: The change of likelihood of a farmer's investing in a milling machine following a capital injection like that of Fadama II is more positive in an environment with higher risks to the price of gari (cassava processed without using a milling machine). (22)

Hypothesis 1 is tested empirically by testing whether condition (19) holds, and similarly condition (20) for hypothesis 2. Hypotheses 1 and 2 may not hold if (a) farmers are not averse to the *gari* price risk and rainfall risk because they have other means to insure themselves, (b) farmers are not risk-averse at all, or (c) Fadama financial assistance is large enough so that farmers can invest in many productive assets. Whether conditions (19) or (20) hold or not is important in understanding farmers' capability of insuring themselves against market and rainfall uncertainty, which are tested through the empirical analyses in the next sections.

3. EMPIRICAL STRATEGY

Our empirical models regress farmers' decisions on investment in irrigation pumps and milling machines on Fadama II membership status, level of rainfall risk, and level of *gari* price risk. The estimation method exploits the panel structure of the dataset. More specifically, the general specification of our model is the following. For each farmer (subscript dropped),

$$\Delta y_t = f\left(\Delta E_t, \Delta F_t, \theta_r, \theta_g, \Psi, \Gamma\right), \tag{23}$$

in which $y_t \in \{P_t, M_t\}$ is a dummy variable that equals 1 if the farmer invests in productive assets (irrigation pump, milling machine) in t = 2006, 0 otherwise, and is determined by function f. E_t is a dummy variable that equals 1 if a farmer belongs to the local government area in which farmers are eligible to participate in the Fadama II program (called *Fadama II LGA* hereafter), and F_t is a dummy variable that equals 1 if a farmer actually participates in the Fadama II program. Therefore $(E_t, F_t) = (1, 1)$ for a Fadama II member, $(E_t, F_t) = (1, 0)$ for non-member of Fadama II in a Fadama II LGA (called *Fadama II neighbor* hereafter), and $(E_t, F_t) = (0, 0)$ for other farmers. The symbol Δ denotes the first difference, so that $\Delta y_t = y_t - y_{t-1}$ and similarly for ΔF_t and ΔE_t. Since the Fadama II project started in 2006, $F_{t-1} = E_{t-1} = 0$, and thus $\Delta F_t = F_t$ and $\Delta E_t = E_t$. Variable ΔE_t is used to control for the effects arising from various components of the Fadama II program, which has significant externality, such as road construction. Other variables include a state dummy (Ψ); risk variables θ_r and θ_g; and key characteristics of respondents, such as gender and education (Γ). It must be noted that equation (23) does not include the average return from investment. The average return is assumed relatively similar among farmers, or less heterogeneous compared to the risks, and can be omitted from (23). This assumption is required partly due to the lack of data on investment return.

Equation (23) expresses both the irrigation pump equation (ΔP_t as the dependent variable) and the milling machine equation (ΔM_t as the dependent variable). The irrigation pump equation and the milling machine equation are estimated separately instead of jointly, and θ_r only appears in the irrigation pump equation while θ_g only appears in the milling machine equation.

Estimation of (23) needs to account for the potential endogeneity problem behind ΔF_t because both Fadama II participation decisions and investment decisions can be affected by common factors, although Fadama II eligibility (ΔE_t) is exogenous because the Fadama II LGA was selected by the government. This study employs two estimation approaches: (1) LPM with 2SLS specification and (2) stratified PSM.

In the first estimation, LPM is used instead of discrete models such as probit or logit although the dependent variable in equation (23) is binary, because the estimation of the discrete model becomes complicated if endogenous discrete variables are included while LPM with 2SLS specification can provide consistent estimates (Angrst, 2000). Our LPM specification is expressed as

$$\Delta y_t = \alpha + \beta \cdot \left(\Delta F_t \times \theta_r, \Delta F_t \times \theta_g\right) + \gamma \cdot \left(\Delta F_t, \Delta E_t, \Delta E_t \times \Psi, \Delta E_t \times \Gamma\right) + \varepsilon_t, \tag{24}$$

in which ΔF_t and ΔE_t are interacted with time-invariant variables θ_r, θ_g, Ψ, and Γ. All variables containing ΔF_t are instrumented by instrumental variables (IVs). The excluded IVs in this case include characteristics of respondents (age, education) and household size interacted with ΔE_t, θ_r, and θ_g.

In the second method, the stratified PSM extends the standard PSM by using strata based on the level of *gari* price risk and rainfall risk as additional information for matching the sample, as combining the matching based on covariates and propensity score can significantly reduce the bias (Dehejia and Wahba 1999; Stuart and Rubin 2008). The estimation of stratified PSM proceeds in the following way. First, the observations are stratified into two or three groups j based on the levels of *gari* price and rainfall risks. Second, within each stratum, standard PSM is conducted on the Fadama II membership status, which gives us the average treatment effect (ATE) for stratum j of Fadama II membership on farmers' investment in productive assets. The estimated ATE_j are then compared across groups to test the hypotheses that the ATE_j becomes significantly higher as the target population moves to the stratum with higher risks, which is equivalent to hypotheses (21) and (22).

4. DATA

Descriptive Statistics in Fadama II and Preliminary Assessment of the Hypotheses

This study uses the dataset collected for the evaluation of Fadama II (Fadama II dataset). A detailed description of the data collection framework for the Fadama II dataset is provided in Nkonya et al. (2008). The key descriptive statistics from Fadama II dataset are summarized in Tables 1 and 2. In 2006, 86 producers among 1,281 Fadama II members invested in milling machines while only 5 out of 1,224 Fadama II neighbors and 29 out of 1,253 remaining farmers invested in milling machines (Table 1). Similarly, 212 producers among 1,281 Fadama II members invested in irrigation pumps, while 19 out of 1,224 Fadama II neighbors and 30 out of 1,253 remaining farmers invested in irrigation pumps.

Table 1. Investment in irrigation pumps and milling machines under Fadama II by investor characteristics

	Total observations	Milling machine			Irrigation pump		
		Total	Personal	Group	Total	Personal	Group
Total	3758	120	37	83	261	170	91
Fadama II member	1281	86	23	63	212	126	86
Fadama II neighbor	1224	5	3	2	19	15	4
Non-Fadama II LGA	1253	29	11	18	30	29	1
Male	2629	56	23	33	218	150	68
Female	1124	57	14	43	43	20	23
Owner of milling machine before 2006	167	9	9	0			
Owner of irrigation pump before 2006	257				69	48	21

Source: Calculated from Fadama II dataset by authors.

There were slight differences between male and female respondents in investment behaviors. While a higher percentage of male farmers (8 percent, or 218 out of 2,629) invested in irrigation pumps than did females (4 percent), a higher percentage of female farmers invested in milling machines (5 percent, or 57 out of 1,124) than did male farmers (2 percent). Female investors in milling machines and irrigation pumps tended to own them in groups while male investors tended to own them personally.

In 2005, approximately 5 percent of farmers in the dataset already owned milling machines, either personally or in a group (167 out of 3,758). In 2006, 5 percent (9 of 167) of farmers who already owned a milling machine invested in milling machines again, while only 3 percent (120 – 9 = 111 of 3,591) of those without milling machines before 2006 newly obtained access to a milling machine. Irrigation pumps were already owned by 7 percent (257 out of 3,758) of farmers in 2005. In 2006, 27 percent of those who already owned irrigation pumps invested again in irrigation pumps, while only 5 percent (261 – 69 = 192 out of 3,501) of farmers without irrigation pumps before 2006 newly invested in irrigation pumps. For both milling machines and irrigation pumps, those who had previously invested were more likely to invest again in 2006, indicating that although those farmers had been aware of the profitability of further investment in these assets, they had been unable to invest more due to liquidity constraints. Such a high liquidity constraint is observed from the fact that most households in the dataset, including the households of farmers who had invested in milling machine or irrigation pump, typically spend less than four hundred US dollars per year on overall household expenditure (Table 2)

To measure the levels of risk, we computed coefficients of variation calculated from historical rainfall trends and *gari* prices, which have been widely used as objective measures of rainfall risks (Gaiha and Imai 2004; Quisumbing 1996; Zeller, Diagne, and Mataya 1998) and price risks in the literature. Table 3 presents the coefficient of variation of annual rainfall and monthly price of white *gari* in selected locations. The price of white *gari*[4] was used to represent the market risks facing farmers because of its popularity as a processed commodity.

Table 2. General characteristics of respondentabc

	All observations		Milling machine investor in 2006		Irrigation pump investor in 2006	
	median	SD	median	SD	median	SD
Household size	9	7	9	8	10	7
Age of respondent	42	12	45	12	45	12
Female respondent (%)	30		50		16	
Years of education of respondent	6	6	6	6	6	5
Annual household expenditure in 2005	$239	$35,501	$383	$1,221	$234	$7,349
Total value of assets in 2005[c]	$1,575	$1,900,000	$1,575	$11,417	$2,472	$12,297
Distance to nearest town in 2005 (km)	4	17	4	7	4	10
Distance to nearest all-weather road in 2005 (km)	3	78	4	24	2	124

Source: Calculated from Fadama II dataset by authors.
Note: [a]The number of observations varies for different variables.
[b]All monetary amounts are in US$ with conversion rate of US$1 = 127 NGN.
[c]Asset value includes the value of land owned.

Table 3. Coefficient of variation for annual rainfall and monthly price of white gari in selected locations

State	Annual rainfall			White *gari* monthly price[b]
	Reference city	CV	Years covered[a]	
Adamawa	Yola	.333	1971–2003	.205
Bauchi	Bauchi	.166	1971–1996, 1998, 2000–2006	.213
Gombe	Bauchi	.166	1971–1996, 1998, 2000–2006	.234
Imo	Owerri	.130	1975–1980, 1982–1986, 1989–1992, 1994–1996, 1999, 2001, 2004–2006	.241
Kaduna	Kaduna	.120	1971–1979, 1984–2000, 2002, 2004–2006	.257
Kebbi	Sokoto	.211	1971–1979, 1981–1982, 1985–2006	.240
FCT	Abuja	.096	1983–2001, 2004, 2006	.260
Lagos	Ikeja	.158	1975, 1977, 1986, 1987, 1989–1992, 1995, 1996, 1998, 1999, 2001, 2003–2005	.259
Niger	Minna	.140	1971–1975, 1977–1979, 1983–1987, 1989, 1991, 1993–1996, 1998–2006	.284
Ogun	Ijebu Ode	.150	1996–2005	.323
Oyo	Ibadan	.204	1975–2005	.297
Taraba	Yola	.333	1971–2003	.227

Source: Calculated by the authors from NIMET (2009) for rainfall data except Adamawa and Taraba, whose numbers are extracted from Oyekale (2009), and NBS (2007) for white *gari* price data.
Note: [a]Years with periods where data were missing were excluded. The duration of total years also depended on the data availability.
[b]Period of coverage for white *gari* price is from January 2001 through September 2005.

[4] Although there are two types of *gari*, yellow *gari* and white *gari*, the movement of their prices is almost identical, so it is safe to use white *gari* prices to obtain the market price risks index in Table 3.

Acquisition of Productive Assets under Fadama II: Key Implications

The purpose of this study is to assess the link between risks and farmers' investment in productive assets, not to evaluate the Fadama II program. Description of the Fadama II program is therefore minimized in this study. Here we provide only the basic picture and components that are relevant to our study.

Fadama II was one of the World Bank and African Development Bank assisted agricultural development programs aimed at addressing productivity growth constraints in Nigeria. Fadama II operated on the concept of community-driven development. Pilot asset acquisition is one of the key components of Fadama II, and it provides assistance for the purchase of moderately priced productive assets, such as irrigation pumps and milling machines.

The process of obtaining productive assets under Fadama II starts when farmers decide to participate in the Fadama User Group, based only on their readiness to contribute their own funds as required for various activities agreed upon by the members and carried out by the group, including the purchase of productive assets at subsidized costs. Once all members of the group agree to obtain particular productive assets, the members purchase them as a group or individually by receiving a 70% subsidy of the price, or up to the equivalent of US$500 for the entire group. Irrigation pumps, for example, are purchased through advertisement to prospective suppliers and a bidding process. In principle, each farmer in the group can obtain a different type of irrigation pump or milling machine based on their needs. The process of acquiring these productive assets can be time-consuming and is assumed to vary widely across states and regions.[5]

Aside from pump or milling machine acquisition, Fadama II provides various other benefits to members, including construction of roads and advisory services on production, processing, storage, and marketing. The investment by Fadama II members in irrigation pumps or milling machines therefore also affects the other Fadama II neighbors. In our empirical estimation, such neighboring effects are controlled for by variable ΔE_t and various interactions terms.

[5] The processes for Fadama User Group of preparing development plans or proposals (for example, to purchase irrigation pumps) typically takes about 13 to 14 weeks, followed by assessment and screening of proposals by the Fadama II supervising bodies.

5. EMPIRICAL RESULTS

This section shows the empirical results. We first briefly show the results supporting homogeneous return on milling machines. We then show key results on the empirical tests of hypotheses (21) and (22) using LPM and stratified PSM.

We first ran a simple regression to see how homogeneous the average return may be across farmers. As was mentioned in section 3, our empirical methods require that, unlike the risks associated with rainfall and *gari* price, the average return from investment in irrigation pumps and milling machines will not vary across states. Although not comprehensive, we used the sub-sample of farmers reporting the difference in price between processed commodities and raw commodities, which can roughly indicate the return for a milling machine. More specifically, 221 reported percentage differences in these two prices were regressed on key variables such as Fadama II membership, state, distance to nearest town, and crop dummies (Table 4). We found that most of these variables are insignificant or significant only at the 10% level, and the return from the processed commodity relative to the raw product price does not seem to vary significantly across states nor does it depend on Fadama II membership or distance to the nearest town.

Table 4. Regional variation in percent price difference between processed products and raw products[a]

Dependent variable: % difference in prices between processed products and raw products	Coefficient	SE
Fadama II member	.336	(.258)
Fadama II eligibility	.027	(.262)
Distance to nearest town	-.014	(.010)
Fadama II member × Distance	-.010	(.012)
Fadama II eligibility × Distance	.021*	(.011)
State 2	-.594	(.923)
State 3	-.299	(1.510)
State 4	.345	(.641)
State 5	-.209	(1.160)
State 6	.113	(1.307)
State 7	.158	(.625)
State 8	1.463**	(.682)
State 9	.110	(.547)
State 10	1.399*	(.722)
State 11	-1.287*	(.669)
State 12	.553	(.577)
Intercept	-3.543*	(1.822)
Number of observations	221	

Source: Authors.
Note: [a]Dummies for products are dropped.*** Significant at 1%; ** Significant at 5%; * Significant at 10%.

2SLS results (Tables 5 and 6)

The results of 2SLS regression (24) are presented in Table 5 (for irrigation pumps) and Table 6 (for milling machines) together with the ordinary least square (OLS) versions for comparison.[6] The results of

[6] The set of variables for household characteristics used in 2SLS and PSM in this study is different from those used for PSM in Nkonya et al. (2008). Nkonya et al. (2008) used area of rainfed land, distance to nearest town and all-weather road, and value of productive assets and livestock before the project in addition to the variables of gender, household size, age, and education level used in this study. This study, however, dropped the former variables because their inclusion caused various identification problems in 2SLS, such as overidentification and underidentification that are reported at the bottoms of Table 5 and Table 6. In PSM, this study uses the same set of variables as IVs that are used in 2SLS to maintain consistency.

first stage regressions in 2SLS are presented in Tables 7 and 8. As was discussed in Section 3, since most variables are first-differenced, many of the variables measuring characteristics of the farrmer's household are dropped and only appear in interaction terms.

Table 5. Determinants of farmers' investment in irrigation pumpsab

Dependent variable	OLS		2SLS	
(= 1 if invested in 2006, = 0 otherwise)	Coefficient	SE[b]	Coefficient	SE[b]
Fadama II member	.163***	(.011)	.094*	(.056)
Fadama II member × rainfall risk	.024	(.127)	1.534**	(.701)
Eligibility	.017	(.019)	-.058	(.053)
Eligibility × gender of respondent	-.080***	(.011)	-.072***	(.014)
Eligibility × State 2	-.051**	(.024)		
Eligibility × State 3	-.074***	(.022)	.053	(.060)
Eligibility × State 4	-.085***	(.022)	.082	(.076)
Eligibility × State 5	.080**	(.029)	.227***	(.078)
Eligibility × State 6	.182***	(.035)	.275***	(.053)
Eligibility × State 7	-.024	(.025)	.171*	(.089)
Eligibility × State 8	-.024	(.025)	.109*	(.064)
Eligibility × State 9	-.079***	(.022)	.069	(.069)
Eligibility × State 10	.076***	(.029)	.216***	(.069)
Eligibility × State 11	.027	(.029)	.123**	(.051)
Eligibility × State 12	-.064**	(.023)	-.069***	(.024)
Intercept	.024***	(.004)	.022***	(.005)
R-square	.152	.171	.111	
p-value				
H_0: No overall significance	.000		.000	
H_0: No endogeneity (Hausman)			.052	
H_0: Not overidentified			.281	
H_0: Underidentified			.000	
Number of observations	3,740		3,182	

Source: Authors.
Note: [a]When the education variable is included as external IV, the number of observations drops to 3,182. In the OLS, we present the results using all 3,740 observations.
[b]Numbers in parentheses are estimated standard errors.
*** Significant at 1%; ** Significant at 5%; * Significant at 10%.

In Table 5, variables including Fadama II membership were found endogenous to the decisions on irrigation pump investment based on the Hausman test[7]. The results of 2SLS estimates in Table 5 indicate that farmers who were Fadama II members were more likely to invest in irrigation pumps, and this impact of Fadama II membership was higher when farmers were facing higher rainfall risk. The positive effect of rainfall risk on farmers' investment in irrigation pumps therefore supports our hypothesis (21) that farmers invest in an irrigation pump in order partly to mitigate the effects of rainfall risk. A significant effect of rainfall risk on irrigation pump investment indicates that farmers in the dataset lack the resources to mitigate the rainfall risk and lack the access to effective agricultural insurance services.

The results for milling machines in Table 6 are more nuanced. Unlike the case for irrigation pumps, there was less clear evidence that variables including Fadama II membership were endogenous to the decisions on milling machine investment (Hausman test). Results from both OLS and 2SLS need to be interpreted.

[7] We used the regression-based form of the Hausman test (Wooldridge, 2002, p.118) which is asymptotically equivalent to the original form of the Hausman test proposed by Hausman (1978).

Table 6. Determinants of farmers' investment in milling machinesab

Dependent variable (= 1 if invested in 2006, = 0 otherwise)	OLS		2SLS	
	Coefficient	SE[b]	Coefficient	SE[b]
Fadama II member	.062***	(.007)	.071	(.054)
Fadama II member × price risk of *gari*	.620**	(.261)	-.146	(1.654)
Eligibility	-.010	(.009)	-.034	(.054)
Eligibility × gender of respondent	.028***	(.010)	.027	(.018)
Eligibility × education of respondent (10 years)	-.013*	(.007)	-.012	(.011)
Eligibility × State 3	.027	(.018)	.038	(.025)
Eligibility × State 4	.001	(.015)	.013	(.028)
Eligibility × State 5	.003	(.017)	.023	(.045)
Eligibility × State 6	-.027	(.008)	-.013	(.028)
Eligibility × State 7	.114***	(.029)	.135**	(.055)
Eligibility × State 8	-.022*	(.012)	-.001	(.044)
Eligibility × State 9	-.043***	(.012)	-.012	(.064)
Eligibility × State 10	.003	(.012)	.048	(.091)
Eligibility × State 11	.013	(.015)	.049	(.081)
Eligibility × State 12	.019	(.016)	.029	(.051)
Intercept	.010***	(.003)	.010***	(.003)
R-square	.074		.069	
p-value				
H_0: not overidentified			.648	
H_0: underidentified			.088	
Overall significance	.000		.000	
H_0: No endogeneity (Hausman test)	.914			
Number of observations	3,182		3,182	

Source: Authors.
Note: [a]Price risk is the coefficient of variation for white *gari*.
[b]Numbers in parentheses are estimated standard errors.
*** Significant at 1%; ** Significant at 5%; * Significant at 10%

The effect of *gari* price risk on Fadama II member farmers' investment in milling machines was found significantly positive in the OLS but insignificant in the 2SLS due to inflated standard errors. Although the findings are not as conclusive as the case for irrigation pumps, the results for milling machines still provide indication supporting the hypothesis (22). With the availability of external capital injection such as Fadama II, farmers facing higher *gari* price risk are more likely to invest in milling machines, which make it possible to process cassava into flour instead of *gari*.

The discussion of results on other variables (eligibility for Fadama II, gender, education, and state) are secondary in this paper, and only key findings are pointed out. The effects of Fadama II eligibility seem to vary from state to state, as do the effects of some characteristics of farmers, such as gender and education. Female farmers who live in the Fadama II LGA, for example, are less likely than males to invest in irrigation pumps, while they are actually more likely to invest in milling machines.

Table 7. First-stage regression for irrigation pump equation

Dependent variable	Fadama II member		Fadama II member × rainfall risk	
	Coefficient	Robust SE	Coefficient	Robust SE
Excluded instruments				
Eligibility × household size	.010***	(.001)	.000	(.000)
Eligibility × age of respondent	.003***	(.001)	.000	(.000)
Eligibility × education of respondent	.006***	(.002)	-.0002*	(.000)
Eligibility × household size × rainfall risk	.000	(.014)	.011***	(.001)
Eligibility × age × rainfall risk	.013	(.010)	.003***	(.001)

Table 7. Continued

Dependent variable	Fadama II member		Fadama II member × rainfall risk	
	Coefficient	Robust SE	Coefficient	Robust SE
Eligibility × education × rainfall risk	-.056***	(.021)	-.000	(.001)
Included instruments				
Eligibility	.146*	(.083)	.036***	(.007)
Eligibility × State 3	.030	(.089)	-.045***	(.007)
Eligibility × State 4	.088	(.110)	-.060***	(.009)
Eligibility × State 5	.017	(.110)	-.055***	(.009)
Eligibility × State 6	.028	(.071)	-.034***	(.006)
Eligibility × State 7	.095	(.117)	-.072***	(.009)
Eligibility × State 8	.014	(.095)	-.048***	(.008)
Eligibility × State 9	.049	(.098)	-.052***	(.008)
Eligibility × State 10	.046	(.096)	-.051***	(.008)
Eligibility × State 11	.007	(.073)	-.036***	(.006)
Eligibility × State 12	-.044	(.039)	-.005*	(.003)
Eligibility × gender	.163***	(.019)	.003*	(.001)
Intercept	.000	(.013)	.000	(.001)
R-square	.296		.524	
Number of observations	3,182		3,182	

Source: Authors.
Note: *** Significant at 1%; ** Significant at 5%; * Significant at 10%.

Table 8. First-stage regression for milling machine equation

Dependent variable	Fadama II member		Fadama II member × *gari* price risk	
	Coefficient	Robust SE	Coefficient	Robust SE
Excluded instruments				
Eligibility × household size	.010***	(.001)	-.000	(.000)
Eligibility × age of respondent	.003***	(.001)	.000***	(.000)
Eligibility × education of respondent	.005***	(.002)	.000***	(.000)
Eligibility × household size × price risk	-.012	(.038)	.008***	(.001)
Eligibility × age × price risk	.075***	(.024)	.005***	(.001)
Eligibility × education × price risk	.226***	(.054)	.006***	(.002)
Included instruments				
Eligibility	.404***	(.078)	-.012***	(.003)
Eligibility × State 3	-.133**	(.054)	.004**	(.002)
Eligibility × State 4	-.090	(.056)	.004*	(.002)
Eligibility × State 5	-.255***	(.076)	.008**	(.003)
Eligibility × State 6	-.160***	(.058)	.006***	(.002)
Eligibility × State 7	-.177**	(.078)	.009***	(.003)
Eligibility × State 8	-.270***	(.076)	.007***	(.003)
Eligibility × State 9	-.333***	(.098)	.013***	(.003)
Eligibility × State 10	-.525***	(.144)	.018***	(.005)
Eligibility × State 11	-.447***	(.118)	.013***	(.004)
Eligibility × State 12	-.164***	(.049)	.004**	(.002)
Eligibility × gender	.162***	(.019)	.002**	(.001)
Intercept	.000	(.013)	.000	(.001)
R-square	.298		.521	
Number of observations	3,182		3,182	

Source: Authors.
Note: *** Significant at 1%; ** Significant at 5%; * Significant at 10%.

Propensity Score Matching

Tables 9 through 12 report the results from stratified PSM. Tables 11 and 12 report impacts of Fadama II membership on farmers' investment in irrigation pumps and milling machines. For irrigation pump investment, based on the rainfall risk level in Table 3, the four states with the highest rainfall risks (Adamawa, Taraba, Kebbi, and Oyo) were grouped as *high risk group*, the four states with the lowest rainfall risks (Federal Capital Territory (FCT), Kaduna, Imo, and Niger) were grouped as *lower risk group*, and the remaining four states were grouped as *medium risk group*. Probit regressions were run within each group to obtain the propensity scores of farmers for Fadama II participation (Table 9). After the propensity scores were estimated, we drop observations in treatment group (Fadama II member) whose propensity score was higher than the maximum or less than the minimum propensity score of the control groups. Consequently, 840 out of 846 observations in the high rainfall risk group, 589 out of 596 in the medium rainfall risk group, and 702 out of 719 in the low rainfall risk group are matched respectively (at the bottom of Table 9). The impact of Fadama II membership on farmers' investment in irrigation pumps was then estimated as the ATE on treated for each of the three groups.[8] A similar approach was taken for milling machines, with Table 10 showing the results of first-stage probit regression for the milling machine equation and the number of matched observations in each group. It is important to note that, for both the irrigation pump and the milling machine equation, different propensity scores are obtained for the same farmer. These differences are due to the difference in grouping for irrigation pump and for milling machine.[9]

Table 9. First-stage probit for PSM (by rainfall risk)

Dependent variable = 1 if Fadama II member, = 0 otherwise	High risk		Medium risk		Low risk	
	Coefficient	SE	Coefficient	SE	Coefficient	SE
Excluded instruments						
Eligibility × household size	.029*	(.016)	.018	(.042)	.111***	(.034)
Eligibility × age of respondent	.018**	(.007)	-.039	(.029)	.003	(.021)
Eligibility × education of respondent	.040***	(.015)	-.168***	(.055)	.076*	(.046)
Eligibility × gender	.693***	(.165)	.476	(.577)	.975**	(.458)
Eligibility × household size × rainfall risk	.026	(.130)	.019	(1.349)	1.091**	(.512)
Eligibility × age × rainfall risk	-.049	(.067)	-1.444	(.885)	.027	(.317)
Eligibility × education × rainfall risk	-.330**	(.131)	-5.829***	(1.863)	.711	(.702)
Eligibility × gender × rainfall risk	-1.843	(1.522)	.986	(18.111)	9.721	(6.717)
Eligibility × State 3			1.504**	(.630)		
Eligibility × State 4					.335*	(.200)
Eligibility × State 5					.257	(.314)
Eligibility × State 6	-.502	(.413)				
Eligibility × State 7					.973	(.622)
Eligibility × State 8			.616*	(.330)		
Eligibility × State 11	-.686	(.457)				
Eligibility × State 12	-.131	(.126)				
Intercept	-.860***	(.286)	-1.353***	(.421)	-1.060***	(.300)
Overall significance (p-value)	.000		.001		.000	
Number of observations	846		596		719	
Matched observations based on estimated propensity score	840		589		702	

Source: Authors.
Note: *** Significant at 1%; ** Significant at 5%; * Significant at 10%.

[8] This estimation was done by the STATA program "PSMATCH2", developed by Leuven and Sianesi (2003).
[9] The difference is also due to the fact that interaction terms for *gari* price risk are excluded from the irrigation pump equation and interaction terms for rainfall risk are excluded from the milling machine equation. We tested whether including these terms would affect the results and found no significant changes in the results in Table 11 and Table 12.

Table 10. First-stage probit for PSM (by gari price risks)

Dependent variable = 1 if Fadama II member = 0 otherwise	High risk Coefficient	High risk SE	Medium risk Coefficient	Medium risk SE	Low risk Coefficient	Low risk SE
Excluded instruments						
Eligibility × household size	.041**	(.017)	.033***	(.010)	.032	(.021)
Eligibility × age of respondent	-.004	(.010)	.003	(.005)	.015	(.014)
Eligibility × education of respondent	.022	(.024)	.022**	(.010)	-.006	(.023)
Eligibility × gender	.265	(.218)	.396***	(.116)	.382	(.293)
Eligibility × household size × price risk	-.165	(.406)	-.073	(1.078)	.153	(.720)
Eligibility × age × price risk	.464**	(.219)	.406	(.484)	.234	(.430)
Eligibility × education × price risk	.430	(.555)	-.834	(1.066)	.285	(.711)
Eligibility × gender × price risk	5.938	(4.621)	6.974	(11.64)	-.862	(9.007)
Eligibility × State 3					-.342	(.543)
Eligibility × State 4			.448	(.456)		
Eligibility × State 6			.328	(.425)		
Eligibility × State 7	1.582**	(.690)				
Eligibility × State 8			.009	(.180)		
Eligibility × State 9	.980**	(.459)				
Eligibility × State 11	.536*	(.319)				
Eligibility × State 12					-.433	(.434)
Intercept	-2.106***	(.427)	-.848***	(.305)	-.421	(.396)
Overall significance (p-value)	.000		.000		.000	
Number of observations	742		768		651	
Matched observations based on estimated propensity score	708		764		645	

Source: Authors.
Note: *** Significant at 1%; ** Significant at 5%; * Significant at 10%.

The results in Table 11 indicate that the effect of Fadama II membership on irrigation pump investment increases monotonically as the rainfall risk increases. For example, in the high rainfall risk group, the Fadama II program on average increased the likelihood of farmers' investing in irrigation pumps by 22.2 percentage points, whereas the increase was 11.9 percentage points and 7.2 percentage points for medium and low rainfall risk groups. The results from the PSM are consistent with the results from Table 5, supporting the hypothesis that higher rainfall risks make farmers more likely to invest in irrigation pumps when their liquidity constraint is relaxed.

Table 11. Average treatment effect (ATE) on treated based on propensity score matching by the level of rainfall risk

	High rainfall risk	Medium rainfall risk	Low rainfall risk
Estimated ATE on treated	.222	.119	.072
Standard error	(.024)	(.027)	(.020)

Source: Authors.

On the contrary, the results from PSM on milling machine investment are ambiguous (Table 12). The impacts of Fadama II membership on the likelihood of milling machine investment seem to be significantly positive at all levels of *gari* price risk, but vary at different levels of risk in a non-monotonic way. While the Fadama II program raised the likelihood of milling machine investment by 11.6 percentage points in the high *gari* price risk group, it did so by only 3.0 percentage points in the medium *gari* price risk group, which is lower than the 6.6 percentage points found in the low risk group. The difference in the impacts, however, becomes clearer when only two levels of risk are considered. The higher risk group exhibits an 8.3 percentage point increase in likelihood of investing in a milling machine, while the increase is 5.0 percentage points in the lower risk group. Assuming these estimated percentage points are uncorrelated with each other, their difference is significant at the 10% level.[10] The results thus provide somewhat weak evidence regarding the hypothesis that higher *gari* price risks lead to more investment in milling machines when liquidity constraint is relaxed, but they still point toward the importance of understanding how market risks play important roles in farmers' decisions on investment in productive assets.

Table 12. Average treatment effect (ATE) on treated based on propensity score matching by the level of gari price risk[a]

	Three strata		
	High *gari* price risk	**Medium *gari* price risk**	**Low *gari* price risk**
Estimated ATE on treated	.116	.030	.066
Standard error	(.019)	(.009)	(.016)
	Two strata		
	Higher *gari* price risk		**Lower *gari* price risk**
Estimated ATE on treated	.083		.050
Standard error	(.014)		(.010)

Source: Authors.
Note: [a]In two strata cases, 1,043 out of 1,081 observations in high *gari* price risk group and 1,076 out of 1,080 observations in low *gari* price risk group were matched respectively and used for the estimation of ATE on treated.

[10] Using the estimated standard errors, the standard errors of the difference of two ATE is calculated as $((.014)^2 + (.010)^2)^{1/2} \approx .017$.

6. CONCLUSION

Productive assets play dual roles in risk-prone agriculture in developing countries, improving productivity as well as insuring against risks. Our study shows two examples. Irrigation assets, which principally increase agricultural productivity, shield farmers from exposure to rainfall risk by securing water supply under erratic weather conditions. Milling machines, likewise, not only increase the market value of produce through processing but also protect farmers from exposure to the price risks of unprocessed crops. Our empirical evidence showed that once liquidity constraint was relaxed through the Fadama II policy intervention, farmers' preferences in making investment choices were consistent with the riskiness of the environment in which they lived.

In the above sense, the impacts of Fadama II on irrigation pump and milling machine investments are heterogeneous across farmers because the impacts depend on the level of price and rainfall risks the farmers face. Farmers facing higher risks of *gari* price fluctuation are more willing to invest in milling machines, which allow them to process cassava into flour. Similarly, in the areas with greater rainfall risks, farmers more often used Fadama II funding to acquire irrigation pumps, thereby reducing their exposure to rainfall risks.

When assessing the impacts of a policy intervention that relaxes farmers' liquidity constraint, it is important to take into account the dual role of their productive asset investments. Farmers often aim to improve agricultural productivity as well as reduce their exposure to risks by investing in one asset. In some cases, it is possible that an investment with a lower level of productivity looks inefficient but the inefficiency could be compensated by a reduction of the risks the farmers face. Our examples from Nigeria show that the latter effect can be the main motivation of their investment behavior.

REFERENCES

Angrist, J. D. 2000. *Estimation of limited-dependent variable models with dummy endogenous regressors: Simple strategies for empirical practice*. NBER Technical Working Paper 248, National Bureau of Economics Research, Cambridge, MA.

Barrett, C., and M. Carter. 2006. The economics of poverty traps and persistent poverty: An asset-based approach. *Journal of Development Studies* 42 (2): 178–199.

Dehejia, R., and S. Wahba. 1999. Causal effects in nonexperimental studies: Re-evaluating the evaluation of training programs. *Journal of American Statistical Association* 94: 1053–1062.

Gaiha, R., and K. Imai. 2004. Vulnerability, shocks and persistence of poverty: Estimates for semi-arid rural south India. *Oxford Development Studies* 32 (2): 261–281.

Hausman, J. A. 1978. Specification tests in econometrics. *Econometrica* 46: 1251–1271.

Key, N., E. Sadoulet, and A. de Janvry. 2000. Transactions costs and agricultural household supply response. *American Journal of Agricultural Economics* 82: 245–259.

Koundouri, P., C. Nauges, and V. Tzouvelekas. 2006. Technology adoption under production uncertainty: Theory and application to irrigation technology. *American Journal of Agricultural Economics* 88 (3): 657–670.

Leuven, E., and B. Sianesi. 2003. PSMATCH2: Stata module to perform full Mahalanobis and propensity score matching, common support graphing, and covariate imbalance testing. http://ideas.repec.org/c/boc/bocode/s432001.html. Accessed October 16, 2010.

NBS (National Bureau of Statistics of Nigeria). 2007. Retail prices of selected items. Abuja, Nigeria. Computer Disk.

NIMET (Nigerian Meteorological Agency). 2009. Historical rainfall data. Abuja, Nigeria. Computer Disk.

Nkonya, E., D. Phillip, T. Mogues, J. Pender, M. K. Yahaya, G. Adebowale, T. Arokoyo, and E. Kato. 2008. *From the ground up: Impacts of a pro-poor community-driven development project in Nigeria.* IFPRI Discussion Paper 00756. Washington, D.C.: International Food Policy Research Institute.

Oyekale, A.S. 2009. Climatic variability and its impacts on agricultural income and households' welfare in southern and northern Nigeria. *Electronic Journal of Environmental, Agricultural and Food Chemistry* 8 (1): 13–34.

Onweluzo, J., and M. Eilittä. 2003. Surveying mucuna's utilization as a food in Enugu and Kogi states of Nigeria. *Tropical and Subtropical Agroecosystems* 1: 213–225.

Quisumbing, A. R. 1996. Modeling household behavior in developing countries: Discussion. *American Journal of Agricultural Economics* 78: 1346–1348.

Rosenzweig, M. R., and K. I. Wolpin. 1993. Credit market constraints, consumption smoothing, and the accumulation of durable production assets in low-income countries: Investments in bullocks in India. *Journal of Political Economy* 101 (2): 223–244.

Stuart, E., and D. Rubin. 2008. Matching methods for causal inference: Designing observational studies. In *Best practices in quantitative methods*, ed. J. Osborne. Thousand Oaks, Calif., U.S.A.: Sage Publications.

Taiwo, K. 2006. Utilization potentials of cassava in Nigeria: The domestic and industrial products. *Food Reviews International* 22 (1): 29–42.

Wooldridge, J. M. 2002. Econometric analysis of cross section and panel data. Cambridge, Massachusetts and London, England.: MIT Press.

Zeller, M., A. Diagne, and C. Mataya. 1998. Market access by smallholder farmers in Malawi: Implications for technology adoption, agricultural productivity and crop income. *Agricultural Economics* 19: 219–229.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to http://www.ifpri.org/publications/results/taxonomy%3A468.
All discussion papers can be downloaded free of charge.

1032. *Factors affecting the choices of coping strategies for climate extremes: The case of farmers in the Nile Basin of Ethiopia.* Temesgen Tadesse Deressa, Claudia Ringler, and Rashid M. Hassan, 2010.

1031. *Intellectual property rights, private investment in research, and productivity growth in Indian Agriculture: A review of evidence and options*. Deepthi Kolady, David J. Spielman, and Anthony J. Cavalieri, 2010.

1030. Examining relationships between customary and state institutions in Ghana's decentralized system. Cory Belden, 2010.

1029. *How safe is my food? Assessing the effect of information and credible certification on consumer demand for food safety in developing countries.* Ekin Birol, Devesh Roy, and Maximo Torero, 2010.

1028. *Rehabilitating agriculture and promoting food security following the 2010 Pakistan floods: Insights from South Asian experience.* Paul Dorosh, Sohail Malik, and Marika Krausova, 2010.

1027. *Neighbor effects in the provision of public goods in a young democracy: Evidence from China*. Claudio A. Agostini, Philip H. Brown, and Xiaobo Zhang, 2010.

1026. *Opportunities and challenges of community-based rural drinking water supplies: An analysis of water and sanitation committees in Ghana*. Yan Sun, Felix Asante, and Regina Birner, 2010.

1025. *"Made in China": Crisis begets quality upgrade*. Jianqing Ruan and Xiaobo Zhang, 2010.

1024. *Overview of the agricultural input sector in Ghana*. Marika Krausova and Afua Branoah Banful, 2010.

1023. *Efficacy and adoption of strategies for avian flu control in developing countries: A Delphi study*. Ekin Birol, Dorene Asare-Marfo, and Yorbol Yakhshilikov, 2010.

1022. *Do differences in the scale of irrigation projects generate different impacts on poverty and production*?. Andrew Dillon, 2010.

1021. *Crop price indemnified loans for farmers: A pilot experiment in rural Ghana*. Dean Karlan, Ed Kutsoati, Margaret McMillan, and Chris Udry, 2010.

1020. *Institutional and public expenditure review of Ghana's Ministry of Food and Agriculture*. Shashidhara Kolavalli, Regina Birner, Samuel Benin, Leah Horowitz, Suresh Babu, Kwadwo Asenso-Okyere, Nii Moi Thompson, and John Poku, 2010.

1019. *Building capacities for evidence and outcome-based food policy planning and implementation: The example of the Comprehensive Africa Agriculture Development Programme.* Ousmane Badiane, Sunday P. Odjo, and John M. Ulimwengu, 2010.

1018. *Modeling the global trade and environmental impacts of biofuel policies*. Antoine Bouët, Betina V. Dimaranan, and Hugo Valin, 2010.

1017. *Analyzing nutritional impacts of policies: An empirical study for Malawi*. Olivier Ecker and Matin Qaim, 2010.

1016. *Optimal rainfall insurance contracts for maize producers in Ghana's northern region: A mathematical programming approach*. Francis M. Muamba and John M. Ulimwengu, 2010.

1015. *Impacts of climate change on agriculture and policy options for adaptation: The case of Vietnam*. Bingxin Yu, Tingju Zhu, Clemens Breisinger, and Nguyen Manh Hai, 2010.

1014. *Spatial price transmission and market integration in Senegal's groundnut market*. Ousmane Badiane, John M. Ulimwengu, and Fleur Wouterse, 2010.

1013. *Strategies for adapting to climate change in rural Sub-Saharan Africa: A review of data sources, poverty reduction strategy programs (PRSPs) and national adaptation plans for agriculture (NAPAs) in ASARECA member countries.* Jonathan Makau Nzuma, Michael Waithaka, Richard Mbithi Mulwa, Miriam Kyotalimye, and Gerald Nelson, 2010.

1012. *Do health investments improve agricultural productivity?: Lessons from agricultural household and health research.* Paul E. McNamara, John M. Ulimwengu, and Kenneth L. Leonard, 2010.

1011. *Investigating the role of poultry in livelihoods and the impact of avian flu on livelihoods outcomes in Africa: Evidence from Ethiopia, Ghana, Kenya, and Nigeria.* Ekin Birol, Dorene Asare-Marfo, Gezahegn Ayele, Akwasi Mensa-Bonsu, Lydia Ndirangu, Benjamin Okpukpara, Devesh Roy, and Yorbol Yakhshilikov, 2010.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: +251 11 6463215
Fax: +251 11 6462927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org