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IFPRI Discussion Paper 01198

July 2012

Onset Risk and Draft Animal Investment in Nigeria

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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.

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ABSTRACT

Onset risk, the uncertainty in the onset of rainy season, is an important element of weather risk for African farmers with little access to formal insurance who engage in traditional rainfed farming. A knowledge gap still exists empirically on how onset risk may affect the investment decisions of these farmers. In particular, farm productivity in Africa still depends on substantial labor inputs at the onset of the rainy season, sometimes involving seasonal migration to rural areas. With credit and insurance market failure, poor access to weather-related information, and high labor mobility costs, high and increasing onset risk may affect farmers' demand for farm mechanization. We test this hypothesis by investigating the effect of onset risk on farmers' investment in draft animals in northern and central Nigeria. We use the example of a public project providing farmers with financial support for the acquisition of productive assets. We calculate the onset of the rainy season using daily rainfall data in various locations across Nigeria and identify locations that have experienced increasing, decreasing, or constant onset risk in the past few decades. We then exploit the panel structure of our dataset and employ stratified propensity score matching to estimate the average treatment effect on the treated, differentiated by the onset risk and its change. The results support our hypothesis. Farmers in areas with higher, increasing, or constant onset risk were more likely to invest in draft animals, and such effects are clearer among larger-scale farmers. Linkages are also clearer with onset risk compared to annual rainfall risk.

Keywords: onset risk, rainfall risk, draft animal, external capital injection, stratified propensity score matching, Nigeria

ACKNOWLEDGMENTS

I would like to thank Futoshi Yamauchi, IFPRI-Nigeria brown bag seminar participants in Abuja, Nigeria for their useful comments and suggestions, and the National Fadama Development Office and the Nigerian Meteorological Agency of Nigeria for sharing the historical data of rainfall, Edward Kato and Sheu Salau for making the data accessible for this study. I am also grateful to the Japanese Government for their financial support in conducting this research. I am responsible for all the remaining errors.

1. INTRODUCTION

The agricultural sector in developing countries is often characterized by high risk, risk-averse agents, failure of credit and insurance markets, and high transaction costs. Farmers in such environments practice a variety of informal risk-mitigation measures (Walker and Jodha 1986), ranging from consumption smoothing (Townsend 1994; Rosenzweig and Stark 1989), investment in land, and income diversification to conservation of biodiversity (Di Falco and Chavas 2009). Recent literature has focused on farmers' weather-related risk-mitigating motives in their investments in productive assets (Rosenzweig and Wolpin 1993; Takeshima and Yamauchi 2012). In many of these studies, uncertainty in annual rainfall (*rainfall risk* hereafter) is widely recognized as an important source of risk for farmers, together with other weather-related shocks such as drought and flood.

Yet another source of weather-related risk is the uncertainty in the onset timing of the rainy season (*onset risk*). Farming, input use, and productivity in Sub-Saharan African (SSA) countries are still highly dependent on the onset timing of the rainy season. In traditional agriculture, farming activities such as land preparation, plowing, and planting often need to be completed at the onset of the rainy season to maximize crop yields (Fakorede and Akinyemiju 2003; Haggblade 2005). While many studies analyze the effect of rainfall risk (typically measured as variations in annual rainfall) on farmers' investment behaviors and welfare, fewer studies examine the specific effects of onset risk. Although onset risk is sometimes correlated with rainfall risk, farmers may experience higher onset risk even when they perceive lower rainfall risk, as is shown in this study. Onset risk poses particular challenges compared to rainfall risk. While rainfall risk affects the entire production period for a farmer, onset risk affects the start of farming. Farmers may respond to onset risk differently from rainfall risk, as the onset of the rainy season in SSA may involve switching from nonfarming activities to farming activities, and some seasonal migration of laborers to the farm (Lapworth et al. 2010; van Westen and Klute 1986; van Dijk, Foeken and van Til 2001).

With insurance market failure and lack of reliable forecasting systems, greater onset risk may raise the cost of hiring sufficient labor for farming activities at the beginning of the rainy season. Once the rainy season starts, labor mobility may decrease because some roads in rural areas become impassable. Labor is also inelastic to wages, particularly in remote areas (Jayachandran 2006),[1] so offering higher wages may not lead to a larger labor supply in the short run. Migration can still be costly for many low-income farmers, and weather shocks can further reduce migration (Lewin, Fisher, and Weber 2012). When their liquidity constraint is relaxed, farmers facing greater onset risk may therefore be more likely to invest in the mechanization of farming activities at the beginning of production season, such as through the purchase of draft animals that give farmers more control over the timing of cultivation and enable higher yields (World Bank 2007).

We test this hypothesis by using the example of the Second National Fadama Development Project (Fadama II project) in Nigeria, in which project participants were provided with financial assistance in obtaining productive assets. Takeshima and Yamauchi (2012) suggest that farmers may invest in productive assets partly to mitigate the effect of rainfall risk. We build on their findings by investigating whether investment in laborsaving tools also responds to onset risk. In addition, investment in draft animals is motivated by many other factors beyond onset risk, particularly farm size and wages. We estimate the effects of onset risk across different farm sizes and conduct robustness checks using wage indicators.

Onset risk has been less commonly used in the literature as a factor driving farmers' investment than rainfall risk, partly because the analysis of the former requires more temporally disaggregated rainfall data, typically at the daily level. The level of onset risk can be used in developing index-based insurance (World Bank 2007, 149), and understanding farmers' response to onset risk is important in assessing the potential benefits from such insurance. This study provides key insights into the effect of

[1] While Jayachandran's (2006) focus is on the inelastic labor supply at lower wage rates, it indicates potentially high labor mobility costs.

onset risk using daily rainfall data from various meteorological stations in Nigeria, combined with household survey data collected for the evaluation of the Fadama II project. We estimate the rainy season's onset date based on historical daily rainfall data, although the literature estimating the onset date sometimes incorporates other climatic indicators. We find that external financial assistance leads to more investment in draft animals, particularly by larger-scale farmers who have experienced higher onset risk or have not experienced a decrease in onset risk in the past few decades; these findings are consistent with our hypotheses. Moreover, we find that while the project led to a significant increase in cultivated area in low- or decreasing-risk regions, no such effect is found in high- or non-decreasing-risk regions, further indicating the risk-mitigating rather than area-expansion motive for draft animal investment in the latter environment. In addition, although various methods have been suggested in the literature for determining the rainy season onset date from daily rainfall data, many of them lead to a similar ranking of the cities in Nigeria with regard to onset risk, making our results robust to different formulas for onset date calculations.

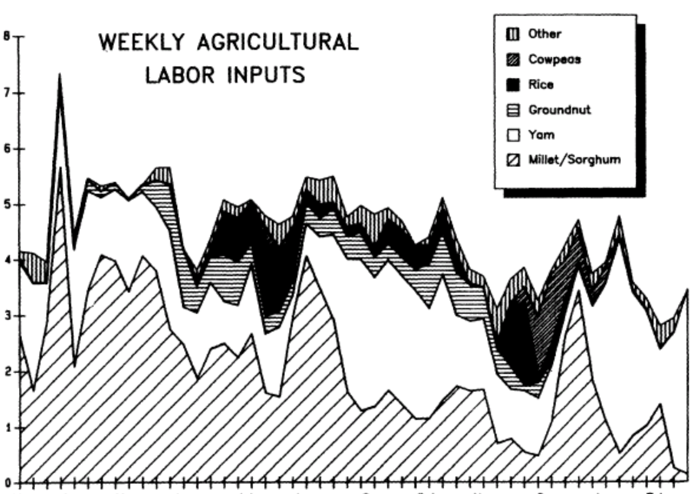
This paper has the following structure. The next section discusses conceptual framework. Section 3 discusses the estimation methodologies and data. Results are discussed in Section 4 and Section 5 concludes.

2. CONCEPTUAL FRAMEWORK AND HYPOTHESES

Northern and central Nigeria have millet- and sorghum-based agro-pastoral farming systems and cereal / root crop mixed farming systems (Dixon, Gulliver, and Gibbon 2001). Rainfed agriculture is still dominant in the region, with only about 5 percent of farmers using any irrigation. The majority of farmers in the region are smallholders cultivating plots under customary tenure, although land is still relatively abundant in northern and central Nigeria compared to southern Nigeria. Although agricultural productivity is still generally low, labor costs represent a significant share of agricultural production costs in Nigeria (Phillip et al. 2009), partly because the rural population—particularly youths—are increasingly leaving agriculture. Among farmers with a relatively larger production scale, however, the level of mechanization has remained low, due not only to the high cost of tractors and power tillers but also to the lack of access to spare parts and reliable repair services, and family as well as hired laborers often provide an important source of farm power (Takeshima and Salau 2010).

Although bush fallow or grass fallow are still common in the region, the gradual shift toward more intensive annual cultivation and multiple cropping has been observed. This approach uses more farm power for intensive land preparation, clearing of land and shrubs, plowing, seedbed preparation, and planting. Plowing is done after the onset of the rainy season, as the soil is often too hard before the rain. The arrival of rain also means that increased farm power is required for weeding, to remove weeds that germinate with rain. Delaying planting after the rain starts often leads to significant yield losses (Stone, Netting, and Stone 1990), typically 1 to 2 percent per day of delay for maize in Nigeria (Fakorede and Akinyemiju 2003)[2] and Zambia (Haggblade 2005). Consequently, farm power demand is typically the highest at the beginning of the production season. For example, in central Nigeria, labor inputs can be almost twice as high in the beginning week of the production season as in the prior week, and substantially higher than in the rest of the production season (Figure 1.1).

Figure 1.1—Mean daily labor inputs per individual (scale in hours) by week



Source: Stone, Netting and Stone (1990, Figure 2).

Note: The figure shows the mean daily labor inputs per individual (scale in hours) for each week in the agricultural calendar, broken down by crop, observed in the villages in central Nigeria studied by Stone, Netting and Stone (1990).

[2] Fakorede and Akinyemiju (2003) estimate that the yield reduction can be 35 to 38 kg/ha per day, which is approximately 2 percent of the maize yield in Nigeria.

Several man-days of manual labor are typically required per hectare for land clearing, seedbed preparation, plowing and planting activities. Use of animal traction could typically reduce the labor requirement by half in Nigeria (Jansen 1993). Similarly, a 0.1 hectare (ha) plot can be plowed in one to one and a half hours if a draft animal is used (Abubakar, Tekwa, and Ahmed 2009), allowing farmers to complete the plowing of 1 ha in a day or two instead of several days. Although the exact farming activities and farm power use patterns vary across farmers, the use of animal traction and one manual worker can, roughly speaking, complete the farming activities up to planting roughly 10 days faster per hectare than using the manual worker alone. Alternatively, a farmer using six manual workers to complete these activities in one week can perform the same work with only three workers if a draft animal is used, significantly reducing the need to hire workers. Much of the north and parts of central Nigeria are naturally suitable for the use of draft animals, such as oxen or bulls, due to the sandy soil that requires less traction power than the hard soil in the south (Abubakar, Tekwa, and Ahmed 2009) and the absence of tsetse flies that harm livestock, which are also prevalent in southern Nigeria. The price of draft animals can constrain their adoption, as a pair of work bulls or oxen can cost as much as 30,000 Naira (approximately US$200) in Nigeria (Ja'afar-furo 2010).

Generally rising agricultural labor costs, farming intensification, higher demand for farm power at the onset of the rainy season, and the relative benefits of draft animals compared to manual labor all suggest that a significant mass of farmers in northern and central Nigeria have sufficiently high potential demand for draft animals, and financial assistance could significantly raise investment in draft animals. The existence of such conditions is important for this study because, although our focus is on farmers' draft animal investment as insurance against onset risk, their investment motive may also be determined by the general profitability of draft animals. In other words, if the productivity return from draft animals is not sufficiently high, farmers who choose insurance mechanisms against onset risk are unlikely to do so through draft animal investment.

The insurance role of draft animals, we hypothesize, is based on the premise (discussed in the previous section) that owning draft animals can reduce the need at the onset of the rainy season to mobilize large labor resources, both the farmer's own family members and hired laborers, and that such mobilization potentially involves risk under uncertain onset timing[3] due to its irreversibility in the short term around the onset period. These decisions may be irreversible in the short term for a number of reasons. Labor mobility costs can be high in rural areas due to poor road conditions, particularly in the rainy season. Poor communication infrastructure could raise the coordination costs for hirers.

The effect of onset risk on farmers' utility linked to their labor resource allocation, the insurance role of draft animals, and the effect of reduced liquidity constraints on their draft animal investments can be illustrated in a simple utility maximization problem in the following way. A farmer maximizes utility U subject to

$$\begin{aligned}
&\max_{\ell_t, L_t, M, X_t} U(X_T, \Pi_t) \\
&\text{s.t.} \\
&\Pi_T = \int_0^T f_t(\ell_t, M, t')dt \\
&G_T = \int_0^T g_t(L_t)dt \\
&X_T = \int_0^T X_t dt
\end{aligned} \tag{1}$$

[3] In Nigeria, several institutions such as the Nigerian Meteorological Agency (NIMET) and the Institute of Agricultural Research (IAR) predict the expected onset of the rainy season and make the information publicly available (NIMET 2011). Accurate forecasting is still challenging, however, and typically the onset date is predicted with a margin of error similar to the magnitude of uncertainty discussed below. In addition, a majority of Nigerian farmers may not have access to this information due to the shortage of extension agents who are primarily in charge of disseminating information to farmers in various locations.

$$A + G_\tau - M\, w(1 - F \cdot \psi) - \int_0^\tau (\ell_t + L_t)dt \; - X_\tau \geq 0,\ \forall\, \tau \in \{0, T\}.$$

U is a function of total consumption X_T and discounted future return from farming activities Π_T realized between a particular period from $t = 0$ to T, which may not be the entire year but a sufficiently long interval that contains all months in which the onset of the rainy season can occur. The farmer maximizes *U* by choosing the optimal level of labor resources ℓ_t and L_t at each *t* and deciding whether to make a new investment in a draft animal ($M = 1$) or not ($M = 0$) at some point between $t = 0$ and *T*. The farmer earns Π from farm activity at *t* (f_t) and nonfarm activity (g_t) by allocating labor resources ℓ_t and L_t. Π_T can be the discounted value of the harvest that could be realized after $t = T$ but depends on the resource use for current farming activities. The farmer still balances current consumption X_T and discounted future return Π_T when maximizing the utility *U*. ℓ_t and L_t can be the opportunity costs of the household labor force or payment for hired labor, which are treated as perfectly substitutable for simplicity. The farming activities f_t depend on whether the new investment in a draft animal is made ($M = 1$). Liquidity constraint for each period $t = \tau \in \{0, T\}$ states that investment in *M* at $t = \tau$ can be made only if the investment *w* does not exceed the total initial wealth available *A* at $t = 0$, plus any earning from nonfarming activities up to τ (G_τ), minus the total labor resource uses and consumption up to τ ($\int_0^\tau (\ell_t + L_t)dt \; - X_\tau$). Investment in *M* is, however, subsidized by ψ if a farmer participates in the project ($F = 1$) that provides financial assistance.

Marginal return of labor in farm activity $f_{t\ell}$ ($= \partial f_t / \partial \ell$) depends on the onset of the rainy season t'. While $f_{t\ell}$ is low before the onset ($t < t'$), as farming activity before the rain starts does not add much value to crop production, $f_{t\ell}$ rises after the onset ($t \geq t'$). $f_{t\ell}$ also depends on the availability of draft animal *M*. The marginal value product of labor in nonfarm activity g_{tL} ($= \partial g_t / \partial L$) is assumed independent of t'.

The solution of the utility maximization problem (1) suggests that optimal ℓ_t* and L_t* satisfy the interior solution

$$f_{t\ell}^* = \partial f_t / \partial \ell_t \mid_{\ell t = \ell t^*} = g_{tL}^* = \partial g_t / \partial L_t \mid_{Lt = Lt^*} \tag{2}$$

or corner solutions

$$(\ell_t, L_t) = (0, L_t^*) \text{ if } f_{t\ell}^* < g_{tL}^*$$

and

$$(\ell_t, L_t) = (\ell_t^*, 0) \text{ if } f_{t\ell}^* > g_{tL}^*. \tag{3}$$

For a farmer who expects the return from farming activity to be below the return from nonfarming activity before the onset t' but reverse at the onset t',

$$f_{t\ell} \lesseqgtr g_{tL} \text{ if } t \lesseqgtr t'. \tag{4}$$

The optimal ℓ_t* and L_t* are likely to change discontinuously at t'. Condition (3) is one such example where a farmer switches completely from nonfarming activity to farming activity at t'.

With uncertainty in onset t', solving the utility maximization involves choosing the timing of such a switch $t = t^*$, which is the farmer's prediction of t'. The farmer's utility from choosing t^* can be expressed as

$$V(A, F, \psi, w, f, g, M, t', t^*), \tag{5}$$

in which the indirect utility function V specifies that the farmer's utility depends on t' and t^*.[4] In the example of (3),

$$V(A, F, \psi, w, f, g, M, t', t^*) =$$
$$U\left\{\int_0^{t^*}\left[f_t(\cdot \mid \ell_t = 0) + g_t(\cdot \mid L_t = L_t^*)\right]dt,\ \ \int_{t^*}^{T}\left[f_t(\cdot \mid \ell_t = \ell_t^*) + g_t(L_t \mid L_t = 0)\right]dt\right\} \tag{6}$$
$$= U\left[\int_0^{t^*} g_t(L_t^*)dt,\ \ \int_{t^*}^{T} f_t(\ell_t^*, M, t')dt\right].$$

Due to the uncertainty in t', choosing t^* can involve risk. For example, farmers cannot easily reallocate the resources they have allocated for farming activities, either by their own family labor force or financial commitment for hired labor, back to nonfarm activities due to various information failures and high migration and transaction costs, which are common in Sub-Saharan Africa. Greater uncertainty in the onset of the rainy season may raise the cost of securing a labor force for farming activities at the onset of the rainy season. When the farmer owns an insufficient number of draft animals ($M = 0$), the expected utility is

$$\mathrm{E}[V \mid M = 0] = \int V(\cdot, t', \cdot \mid M = 0)h(t')dt', \tag{7}$$

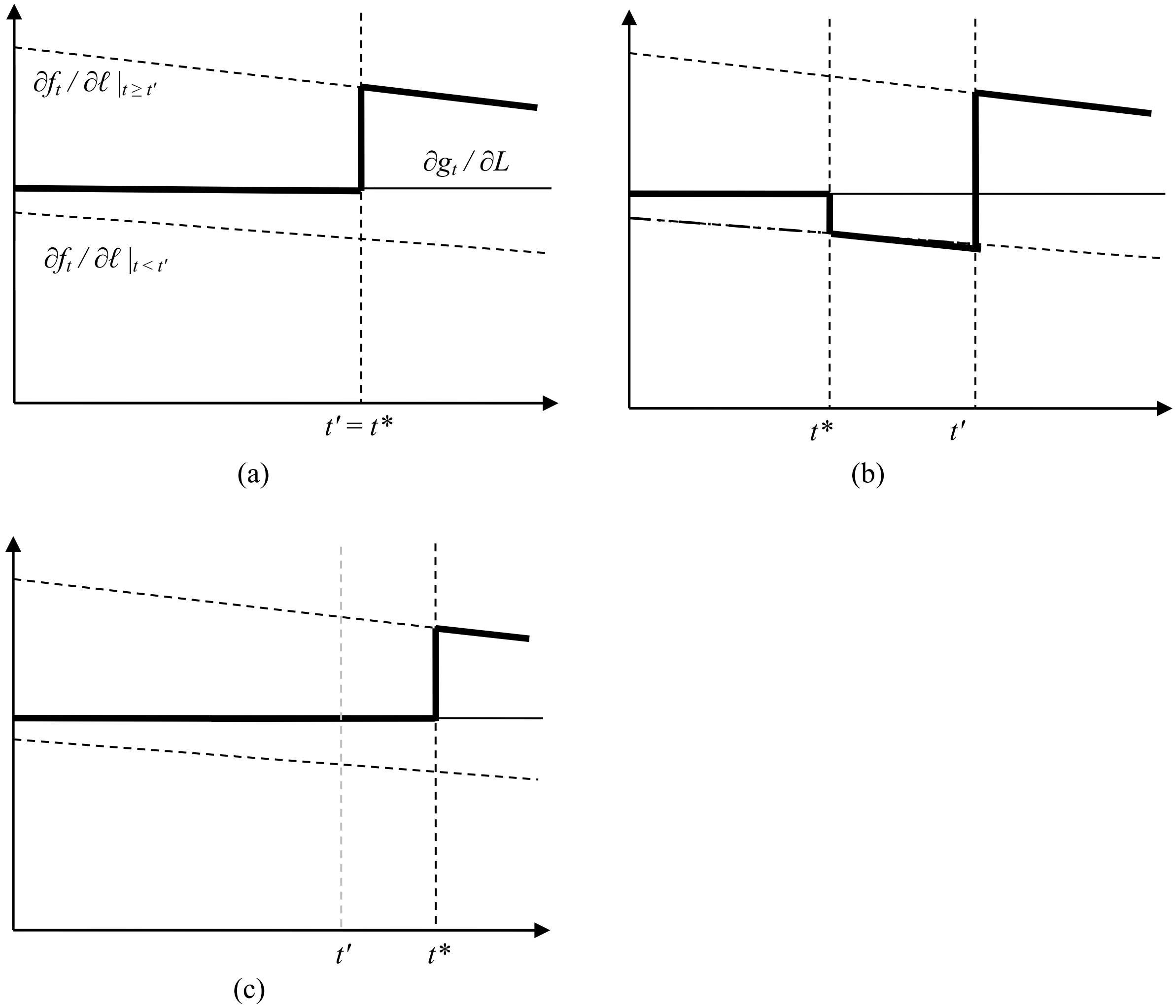
where expectation is taken over the possible range of t', which is randomly distributed based on density function $h(t')$ with standard deviation σ.

Figure 2.1 illustrates simple examples of the linkage between risk associated with the selection of t^* and realization of t'. For illustrational purpose, Figure 2.1 shows the case in which $f_{t\ell}$ and g_{tL} are constant across all ℓ_t and L_t given t'. In (a), a farmer can select t^* exactly at $t^* = t'$, and earns marginal return g_{tL} until $t = t'$ and $f_{t\ell}|_{t \geq t'}$ from $t = t'$. In (b), a farmer preselects t^* but the rain does not come on time. The marginal return drops to $f_{t\ell}|_{t < t'}$ from g_{tL} between t^* and t'. At the onset t', the marginal return jumps up to $f_{t\ell}|_{t \geq t'}$. Similarly, in (c), the onset comes earlier than the farmer's prediction t^* and he loses the potential gains. In Figure 2.1, the marginal return for farming activity declines slightly over time due to the aforementioned effect of planting delay on yield. In addition, due to the absence of early maturing varieties, farmers may prefer to start the planting as early as possible once the onset comes, so that they can harvest the crops as early as possible to earn a higher market price before the market becomes saturated with the harvest by other farmers, or to shorten the lean season and enable more effective consumption smoothing (Netting and Stone 1996). Such declining returns also suggest that choosing a later t^* may be as risky as choosing an early t^*. Due to the scarcity of information, we assume that farmers' perception of risk σ is constant for all t^*. A draft animal can make the uncertainty in t' irrelevant, as it allows a farmer to start farm activity whenever t' is observed. Therefore,

$$\mathrm{E}[V \mid M = 1] = V(\cdot, t', \cdot \mid M = 1). \tag{8}$$

[4] We assume that farmers can perceive t' correctly once it arrives. The case in which farmers cannot correctly perceive t' is beyond the scope of this study, as it requires more complicated modeling of farmers' perception processes. We define the onset date using a particular formula and obtain empirical uncertainty based on historical realizations. We believe such empirical uncertainty can be a good measure of farmers' perceptions of uncertainty, as they often build their forecast based on their experience, as well as the experience of their ancestors passed down to them through oral tradition (Nnoli et al. 2006).

Figure 2.1—Onset of rainy season (t') and returns from decision of timing t^*



Source: Author.

The indirect utility function V is concave in rainfall onset date so that $\partial^2 V(\cdot)/\partial\sigma^2 < 0$ for a risk-averse farmer. Following Takeshima and Yamauchi (2012), if an external capital injection ($F = 1$) allows farmers to invest in draft animals, which can shield them from onset risk, we have

$$\frac{\partial E[V \mid M=0, F=1]}{\partial\sigma} < \frac{\partial E[V \mid M=1, F=1]}{\partial\sigma} \leq 0\,, \tag{9}$$

in which $E[V \mid M = 0, F = 1)]$ is the expected utility of a farmer who is a project beneficiary but does not invest in a draft animal. The equality holds if investment in draft animals makes farmers completely free from onset risk. Condition (9) suggests,

$$\frac{\partial\left\{E[V \mid M=0, F=1] - E[V \mid M=1, F=1]\right\}}{\partial\sigma} < 0\,. \tag{10}$$

However, in the absence of external capital injection ($F = 0$), farmers may not invest in draft animals even though their potential demand may vary based on the onset risk, so that

$$\frac{\partial\{E[V \mid M=0, F=0] - E[V \mid M=1, F=0]\}}{\partial\sigma} = 0\,. \tag{11}$$

Conditions (10) and (11) indicate the following empirical conditions:

$$\frac{\partial \Pr(M=1 \mid F=1)}{\partial\sigma} - \frac{\partial \Pr(M=1 \mid F=0)}{\partial\sigma} = \frac{\partial \Pr(M=1 \mid F=1)}{\partial\sigma} > 0\,. \tag{12}$$

In other words, when onset is less certain (greater σ), the external capital injection has a greater impact on the likelihood of draft animal investment.

Importantly, empirical condition (12) is more likely to hold for farmers whose demand for draft animals is sufficiently high that they would actually make the investment with a certain amount of external capital injection. Farmers cultivating larger plot areas may have such high initial demand because they are likely to rely on hired labor, whose costs may be more susceptible to onset risk, and returns from draft animal investment may be sufficiently high given the economy of scale, compared to farmers cultivating smaller plot areas. In other words, larger-scale farmers may be more sensitive to onset risk, so that we have the following empirical condition:

$$\frac{\partial^2 \Pr(M=1 \mid F=1)}{\partial\sigma\partial\Omega} > 0\,, \tag{13}$$

in which Ω is the farm size.

Altogether, by testing whether (12) and (13) hold, respectively, we test the following two hypotheses:

Hypothesis 1: In an environment with higher onset risks, a capital injection such as that of Fadama II has a greater impact on raising the likelihood of farmers' investment in draft animals. (14)

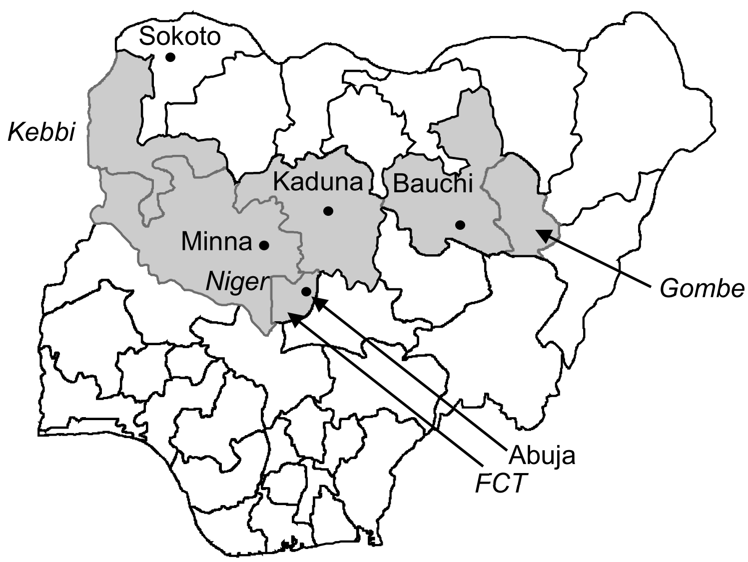
Hypothesis 2: Effects in Hypothesis 1 are greater for farmers with large farm sizes. (15)

These hypotheses may not hold if, among other alternative conditions, (a) farmers are not averse to the onset risk because they have other means to insure themselves, (b) farmers are not risk-averse at all, (c) the external capital injection is insufficient to make draft animal investment profitable, or (d) farmers with large farm sizes have already invested sufficiently in draft animals. Evidence supporting Hypotheses 1 and 2 would suggest that investment in draft animals is partly motivated by insuring against onset risk, which has important implications for agricultural mechanization and climate change adaptation policies in Sub-Saharan Africa.

3. EMPIRICAL METHODS AND DATA

We use the dataset collected for the evaluation of the Second National Fadama Development Project in Nigeria (Fadama II dataset) to analyze investment behaviors in draft animals. We focus our analysis on 6 northern and central Nigerian states out of the 12 states surveyed in Fadama II data, due to the difference in farming systems and use of draft animals in southern Nigeria, and also the lack of rainfall data in a few central states. In addition, we apply rainfall data from Bauchi and Sokoto cities for Gombe state and Kebbi state, respectively. Figure 3.1 illustrates the locations of states and cities for which data were analyzed. Detailed descriptions of data collection are provided in Nkonya et al. (2010) and Takeshima and Yamauchi (2012). The data have a semipanel structure and comprise the information from 2005 (before the project implementation) and 2006 (after the project implementation). Exploiting the semipanel structure of the data, we form our empirical specification in a first difference expression in order to eliminate unobserved heterogeneity and obtain more consistent estimates.

Figure 3.1—States and cities in the analysis (states are in italics)



Source: Author.
Note: Kaduna and Bauchi are also the names of the corresponding states.

We test Hypothesis 1 applying the stratified propensity score matching (PSM) method used in Takeshima and Yamauchi (2012), in which the sample is stratified by states based on the onset risk. Estimation of onset risk and stratification are discussed in the next section. We also further stratify the sample based on the area cultivated by farmers in 2005, to test Hypothesis 2. We estimate the average treatment effects on the treated (ATT) of the Fadama II project on the likelihood of a farmer's investment in at least one draft animal and attachment, namely oxen, ox plow, or work bull, within each stratum. We then test Hypothesis 1 by testing whether the estimated ATTs in higher-risk or non-decreasing-risk groups are statistically significantly positive and greater compared to lower-risk and decreasing-risk groups, and Hypothesis 2 by testing whether the estimated ATTs are greater for farmers with larger farm sizes. Estimation is conducted in Stata using command psmatch2, using the nearest neighbor matching method. Results are robust to different choices of matching methods.

Propensity is the probability that a farmer participates in the Fadama II project. In the first stage, we estimate the probit model,

$$p_i = \Pr[\Delta F_i = 1 \mid \Delta X_i] = \Phi(\Delta E_i \cdot (1, \sigma, \delta, H_i), \beta), \tag{16}$$

in which the probability of farmer i participating in the project depends on the change in eligibility (ΔE), its interaction with onset risk (standard deviation σ), change in onset risk ($\delta = 1$ if onset risk decreased, = 0 otherwise), and other household characteristics H. The eligibility ΔE indicates whether the farmer resides in one of the local government areas (LGAs), which are designated for project implementation (see Takeshima and Yamauchi [2012] for detail). While $\Delta E = 0$ indicates that the respondent resides outside such LGAs and faces more difficulty in participating in the project, the farmer may still participate if he or she is part of an Economic Interest Group (EIG) in the eligible LGA, as application for project grants is made through the EIG. The key assumption for PSM that $0 < p < 1$ therefore holds for all observations, including those with $\Delta E = 0$. β is the vector of estimated parameters.

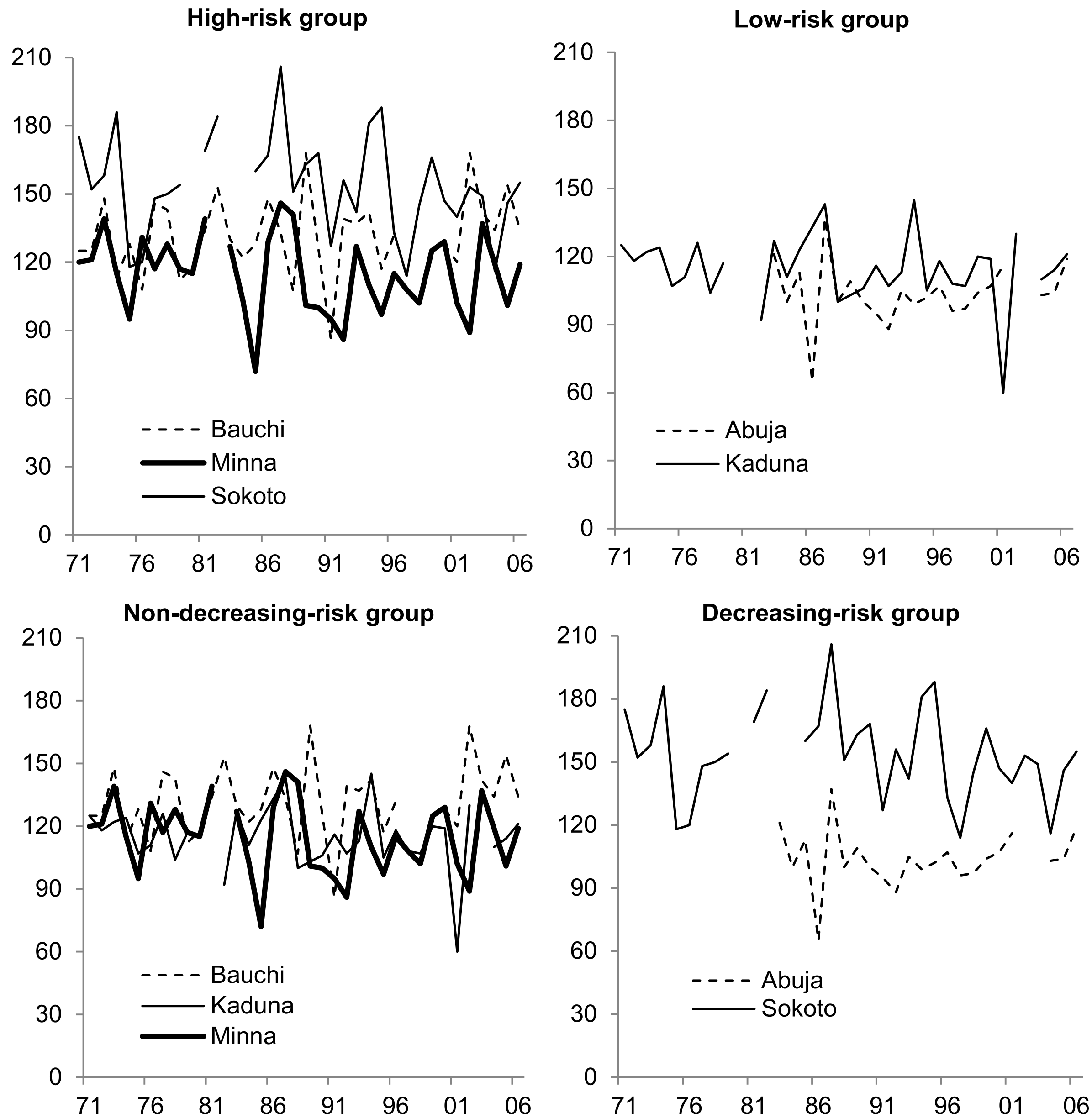
Household characteristics H is a set of all time-invariant variables measured in 2005, including age, gender, education status of respondent, household size, number of working-age household members, area cultivated, whether they already owned some draft animals or an irrigation pump, distance to the nearest town, and state dummy variables. We also estimated the model including LGA average wages for agricultural processing as a proxy of wages for farming activities with fewer observations for which the information was available. Using the predicted probability $\dot{p}_i$ from (16), each observation i in the treated group is matched with the observation in the control group with similar $\dot{p}_j$, and the difference in the outcome (whether i invested in a draft animal in 2006) is obtained for each i. The average of the differences across all i's is measured as ATT. We focus on how the estimated ATTs vary for populations facing different levels of onset risk and its change.

Onset Risk

We identify the rainy season onset dates in five locations across Nigeria using historical daily rainfall data and use the standard deviation as the proxy for onset risk. We consider both long-term onset risk and its short-term fluctuations. The long-term risk is the standard deviation calculated from the entire data period, and the short-term fluctuation is determined by whether the standard deviations change significantly between and after any threshold years.

While the onset of the rainy season in Nigeria is partly determined by the latitude of each location, it varies across locations and years due to variations in the intensity of isolated showers and the duration of dry periods (Walter 1967). Many past studies use daily rainfall data to determine the onset, exploiting the cumulative percentages of daily rainfall (Walter 1967; Ilesanmi 1972; Odekunle 2004, 2005) as well as rainy days (Odekunle 2005), in which onset days depend on total annual rainfall by construction. Sivakumar (1988) provided different criteria, which do not depend on total annual rainfall but are applicable for Sudan Sahel, which is north of Nigeria. Alternatively, Nnoli et al. (2006, 2) use the following criteria: “The beginning of the first 10-day period with cumulative rainfall of greater than or equal to 30mm, one of which is at least 10mm and followed by another two ten-day periods each with at least 8–10 mm rain.” We primarily draw on Nnoli et al. (2006), as this approach is independent of the total rainfall, unlike Ilesammi (1972) or Odekunle (2004), and can be applied to more humid regions in Nigeria other than Sudan Sahel as studied by Sivakumar (1988). We show below, however, that results from Nnoli et al. (2006) are generally robust across different methods. Figure 3.2 plots the onset dates estimated using Nnoli et al. (2006) and how each city falls into each group based on high/low and non-decreasing/decreasing risk, as defined below. Onset dates generally range between the 75th and 175th days of the year (mid-March through late June) for some northern cities (Abuja, Bauchi, Kaduna, Minna) or the 125th through 200th days of the year (early May through late July) for the other northern cities (Sokoto).

Figure 3.2—Onset days based on Nnoli et al. (2006)



Source: Author's calculation from NIMET (2009).
Note: The vertical axis measures the day of the year and the horizontal axis indicates the year of the observations.

Table 3.1 summarizes the standard deviations of onset days at each location, calculated using four different methodologies: Ilesanmi (1972), Odekunle (2005), Nnoli et al. (2006), and Nnoli et al. (2006) with threshold rainfall of 50 millimeters (mm) instead of 30 mm for the first 10 days.[5] Abuja and Kaduna cities have experienced relatively stable (more certain) onset days, while other cities in the north and central zones (Bauchi, Sokoto, Minna) have experienced greater uncertainty. Standard deviations of 13.3 days would mean that the onset dates can be 9 days earlier or later than the average with 50 percent

[5] We also found no evidence of serial correlations of onset dates, indicating that standard deviation may be a fairly good proxy for onset risk (see detail in the appendix).

probability and can differ by more than 17 days with 20 percent probability, while a standard deviation of 21.7 days indicates 15 and 28 days, respectively. Estimated standard deviations of onset days are found jointly statistically significantly different across locations, even given the small sample size, particularly under Odekunle (2005) and Nnoli et al. (2006), based on a robust test by Brown and Forsythe (1974) that does not require an asymptotic normality assumption. Importantly, four methods give similar rankings of cities in terms of onset risk, as indicated by relatively high correlation coefficients between the methodologies (Table 3.2). In most methods, the cities can be ranked in the order of Abuja, Kaduna, Minna, Bauchi, and Sokoto, with Abuja experiencing the lower risk.

Table 3.1—Standard deviations of onset days at each location

City	State in Fadama II data	Methodology				Risk (*H* = high, *L* = low)
		Ilesanmi (1972)	Odekunle (2005)	Nnoli et al. (2006)[b]		
				Threshold = 30 mm	Threshold = 50 mm	
Bauchi	Bauchi, Gombe	14.8	10.4	17.2	18.6	*H*
Kaduna	Kaduna	9.5	8.0	15.2	17.4	*L*
Sokoto	Kebbi	14.8	13.7	21.7	20.9	*H*
Abuja	FCT	11.6	7.5	13.3	14.0	*L*
Minna	Niger	14.1	9.7	16.8	19.7	*H*
p-value for H_0: standard deviation is equal at all locations[a]		.173	.000	.015	.003	

Source: Author's calculation.
Notes: [a] Test based on Brown and Forsythe (1974).
[b] The beginning of the first 10-day period with cumulative rainfall of greater than or equal to either 30 mm or 50 mm. Results are very similar.

Table 3.2—Similarity between different methods (correlation coefficients of onset date uncertainty)

	Ilesanmi (1972)	Odekunle (2005)	Nnoli et al. (2006)
Odekunle (2005)	.934		
Nnoli et al. (2006) – 30 mm	.849	.866	
Nnoli et al. (2006) – 50 mm	.932	.944	.931

Source: Author's calculation.

We also identify the locations that have experienced significant short-term fluctuations in onset risk. Table 3.3 summarizes whether standard deviations in onset dates increased or decreased in each city after any threshold year. Based on the aforementioned Brown and Forsythe (1974) test, we find several threshold years after which standard deviations of onset dates had changed statistically significantly from the prior period. Importantly, the direction of change (whether increase or decrease) in onset risk is found consistent across all such threshold years, so that no city seems to have experienced both an increase and a decrease in onset risk. We therefore use these results as weak evidence that farmers in each city experienced short-term fluctuations (either increase, decrease, or no change) in onset date risk in the past 10 to 30 years (last column of Table 3.3). Sokoto and Abuja experienced a decrease in onset risk, while Minna experienced an increase in onset risk and Bauchi and Kaduna experienced no change.

Table 3.3—Significance of change in onset risk and threshold years (Nnoli et al. 2006)

City	Threshold year based on robust test (Brown and Forsythe 1974)	Change in risk (+: increasing –: decreasing)	
		Onset risk	Rainfall risk
Bauchi		+ ?	0
Kaduna		+ ?	0
Sokoto	1997	–	–
Abuja	1986–1993	–	0
Minna	1980–1984	+	–

Source: Author's calculation.

Notes: The table shows threshold years in which standard deviations of onset dates have significantly increased (+) or decreased (–) from pre- to post-threshold years. For example, in Abuja, the post-1986 period experienced statistically significantly (p-value < 0.1) higher standard deviations than the pre-1986 period. Similarly, the post-1987 period experienced statistically significantly (p-value < 0.1) higher standard deviations than the pre-1987 period.. For Abuja, each year between 1986 and 1993 can be considered a threshold year. Similar threshold years were found for Sokoto and Minna. No such threshold years were found for Bauchi or Kaduna.

A late onset is often negatively correlated with total rainfall that year (Table 3.4). Similarly, onset risk is generally positively correlated with rainfall risk. The significance of their correlation is, however, rather mixed. Patterns of change in onset risk are different from change in rainfall risk. While Sokoto experienced a decrease in onset risk, no change in rainfall risk was observed. Similarly, while Minna experienced an increase in onset risk, it experienced a decrease in rainfall risk. These results also support the motivations of this study to examine specifically the effects of onset risk instead of rainfall risk, which is more commonly studied in the literature.

Table 3.4—Correlation between onset risk and rainfall risk

City	State	Correlation	Onset risk and rainfall risk	
			Rainfall risk = standard deviation	Rainfall risk = coefficient of variation
All			.722**	.295
North			.338	.872***
Bauchi	Bauchi, Gombe	–.100		
Kaduna	Kaduna	–.230		
Sokoto	Kebbi	–.385		
Abuja	FCT	–.263		
Minna	Niger	–.372		

Source: Author's calculation.

Notes: Rainfall risk is obtained from Takeshima and Yamauchi (2012). The numbers are estimated correlation coefficients. *** significant at 1%; ** Significant at 5%.

Stratification and Descriptive Statistics

Using the estimated onset risks, we stratify states in two separate ways. In the first stratification, based on long-term onset risk (Table 3.1), we stratify states into a high onset -risk group (Bauchi, Gombe, Niger, Kebbi) and a lowonset -risk group (Federal Capital Territory [FCT] and Kaduna). In the second stratification, based on the short-term fluctuations in onset risk (Table 3.3), we stratify states into a non-decreasing-risk group (Bauchi, Gombe, Niger, Minna) and a decreasing-risk group (FCT and Kebbi).

Table 3.5 summarizes the key descriptive statistics of farmers with different farm sizes and onset risks. Characteristics of respondents are similar across different farm sizes and onset risks, except the ownership of some draft animals prior to project implementation in 2005, household expenditure, and

LGA average wage. Respondents with larger farm sizes spend almost twice as much (US$212 per month per household) as those with smaller farm sizes, indicating their greater wealth, and are more likely to have owned draft animals in 2005 (21 percent compared to 10 percent). Respondents in high-risk groups are more likely to have owned draft animals in 2005 (24 percent) compared to those with low onset risk (4 percent), but they also face lower wages (US$1.30 per day, compared to US$4 per day) and cultivate slightly more land (2 ha compared to 1.8 ha). Wages are not significantly different between respondents with different farm sizes. The descriptive statistics indicate that ownership of draft animals may be correlated with onset risk as we hypothesize, while its association with wages is somewhat ambiguous.

Table 3.5—Descriptive statistics by farm size in north (median)

	Farm size (2005)		Onset risk	
	≥ 2 ha	< 2 ha	High	Low
Invested in draft animal (oxen, work bull, or ox plow) (%)	**15**	**8**	**17**	**3**
Age	40 (12)	40 (12)	42 (11)	38 (12)
Gender (%)	17	26	19	25
Household size	10 (10)	9 (6)	10 (9)	8 (7)
# of working-age family members	4 (7)	3 (4)	4 (7)	4 (4)
Primary education (%)	52	45	43	58
Secondary education (%)	30	28	28	32
Owned draft animal in (2005) (%)	21	10	24	4
Owned irrigation pump (2005) (%)	10	9	8	11
Distance to nearest town (km)	4 (10)	5 (9)	5 (11)	6 (7)
Fadama II participation	58	47	53	54
Household expenditure (US$/month)	212 (6596)	113 (3934)	144 (7109)	180 (331)
LGA average wage (US$/day)	1.4 (1.5)	1.5 (1.1)	1.3 (0.3)	4 (2)
Farm size (2005)			2.0	1.8
Number of observations	366	289	402	253

Source: Author.

Notes: Numbers in parentheses are standard deviations. The number of observations is smaller for some variables due to missing observations.

4. RESULTS

Results are shown in Tables 4.1 through 4.5. Factors affecting farmers' project participation differ based on the onset risk and changes in it (Table 4.1). In the high onset -risk group, eligible female respondents were more likely to join if they had not experienced decreasing onset risk. Eligible farmers with smaller farm sizes were also more likely to join if they had experienced higher onset risk and had not experienced a decrease in onset risk. Similarly, owning draft animals and living a greater distance from the nearest town together with higher and increasing onset risk raised the likelihood of participation. In the lower-risk group, older farmers experiencing decreasing onset risk were less likely to join the project. Farmers with smaller farm sizes with a larger working-age population were more likely to join if they had not experienced decreasing onset risk. In the non-decreasing-risk group, female farmers experiencing higher onset risk were more likely to join the project. In the group experiencing decreasing onset risk, project participation was more likely for younger farmers with larger household sizes but fewer working-age household members, with secondary education and higher onset risk, and without their own pump and residing closer to the nearest town. Larger farm size was also associated with higher likelihood of project participation, particularly in lower-risk regions. We also ran the specifications including the wage variables and found similar results (not shown). Overall, propensity scores are affected by different factors across groups with different onset risk levels and changes in these levels, indicating potential heterogeneity in project impacts based on onset risk.

Table 4.1—First stage in PSM

	Onset risk				Change in onset risk			
Dependent variable	**High**		**Low**		**Non-decreasing**		**Decreasing**	
(= 1 if invested in 2006, = 0 otherwise)	**Coef**	***z***	**Coef**	***z***	**Coef**	***z***	**Coef**	***z***
ΔE × age	.112	1.15	.008	.85	-.045	-1.51	-.018**	-2.28
ΔE × age × *σ*	7.922	1.21			-1.428	-1.64	.149	.79
ΔE × age × *δ* (decrease = 1)	-.379	-1.25	-.044***	-2.61				
ΔE × gender (female = 1)	.834***	3.06	-.164	-.54	2.365***	2.86	.148	.76
ΔE × gender × *σ*					59.864**	2.37	-2.790	-.60
ΔE × gender × *δ*	-.936**	-2.24	.594	1.26				
ΔE × household size	-.027	-.14	.019	.81	.093	1.49	.068***	3.43
ΔE × household size × *σ*	-6.186	-.48			1.992	1.05	.476	.82
ΔE × household size × *δ*	.305	.50	.027	.54				
ΔE × working age	-.463	-1.28	.006	.17	.055	.53	-.116***	-3.47
ΔE × working age × *σ*	-30.323	-1.29			-.088	-.03	.714	.72
ΔE × working age × *δ*	1.300	1.17	-.205***	-2.47				
ΔE × primary education	-3.923	-.99	.005	.02	-.587	-.73	-.125	-.53
ΔE × primary education × *σ*	11.742	.92			-12.618	-.55	-5.756	-.98
ΔE × primary education × *δ*	-256.367	-.91	.260	.54				
ΔE × secondary education	5.098	1.14	.229	.84	-.183	-.21	.917***	3.56
ΔE × secondary education × *σ*	351.737	1.10			-10.031	-.40	11.163*	1.95
ΔE × secondary education × *δ*	-14.730	-1.01	.041	.09				
ΔE × area in 2005	-.543	-1.64	-.016	-.19	-.038	-.37	.110***	3.13
ΔE × area in 2005 × *σ*	-39.823*	-1.67			-1.906	-.46	-2.761***	-2.61
ΔE × area in 2005 × *δ*	1.850*	1.71	.360***	2.74				
ΔE × owner in 2005	.418*	1.89	.551	1.19	.345	.44	.164	.62
ΔE × owner in 2005 × *σ*					-4.842	-.18		
ΔE × owner in 2005 × *δ*	-.317	-.84						
ΔE × pump in 2005	-.725	-1.40			-1.258	-.90	-.848***	-3.17

Table 4.1—Continued

Dependent variable (= 1 if invested in 2006, = 0 otherwise)	Onset risk: High Coef	z	Onset risk: Low Coef	z	Change in onset risk: Non-decreasing Coef	z	Change in onset risk: Decreasing Coef	z
ΔE × pump in 2005 × σ					-29.771	-.82	1.769	.24
ΔE × pump in 2005 × δ	-.070	-.10	-1.015	-1.58				
ΔE × distance in 2005	.464**	2.37	.012	.85	.009	.34	-.021*	-1.85
ΔE × distance in 2005 × σ	33.389**	2.34			-.158	-.18	-.560	-1.58
ΔE × distance in 2005 × δ	-1.553**	-2.42	-.000	.00				
ΔEligibility × State	Included		Included		Included		Included	
Intercept	Included		Included		Included		Included	
Pseudo R-square	.256		.156		.196		.182	
p-value (H_0: No overall significance)	.000		.000		.000		.000	
Number of observations	402		253		331		324	
Number of matched observations	351		239		296		309	

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

Tables 4.2 and 4.3 show the estimated ATTs for groups with different onset risks and farm sizes. The second and the third columns show the estimated ATTs for all samples regardless of farm size; the third column shows the results when LGA average wage and its interaction terms are added as explanatory variables. In states with higher onset risk, the project raised the likelihood of farmers investing in draft animals by 22.6 percentage points, which was statistically significantly higher (p-value = .002) than the 6.6 percentage points in states with lower onset risk. The findings are also similar when the LGA average wage is included in the set of explanatory variables.

Table 4.2—ATT and onset risk

	All	All (with LGA average wage)	Farm size in 2005 (LGA average wage excluded): ≥ 3 ha	≥ 2 ha	< 3 ha	< 2 ha	p-value (by farm size)
High	.226*** (.047) *351*	.275*** (.061) *213*	.279*** (.074) *134*		.180*** (.050) *221*		.268
				.256*** (.062) *177*		.212*** (.057) *144*	.601
Low	.066*** (.023) *239*	.077*** (.026) *197*			.075** (.032) *156*		
				.025 (.025) *96*		.067* (.038) *105*	.355
p-value (by onset risk)	.002	.003	.000	.001	.077	.034	

Source: Author.
Notes: Numbers in parentheses are the corresponding standard error, italic numbers are the corresponding matched sample sizes, and the p-values in the last column and row indicate the statistical significance of the difference between ATTs from different onset risks or farm sizes. For example, the first p-value in the last column shows the significance of the difference between ATTs for farmers with farm sizes greater than or equal to 3 ha and those with farm sizes less than 3 ha in high-risk regions.
*** Significant at 1%; ** Significant at 5%; * Significant at 10%.

The remaining columns in Table 4.2 show the ATTs estimated for subgroups of farmers differentiated based on farm size in 2005 (preproject year). We use 2 ha and 3 ha as thresholds as they are the 50th and 75th percentiles of farm size in our data, respectively. The estimations for these subgroups are conducted excluding LGA average wage, as the sample size becomes too small. The effect of the onset risk becomes slightly more substantial for farmers with larger farm sizes. Among farmers who cultivated 2 ha or more in 2005, the effect of the project is 25.6 percentage points in the higher onset risk group, which was statistically significant, while the ATT is statistically insignificant in the lower onset risk group. Among farmers who cultivated less than 2 ha in 2005, the ATTs are 21.2 percentage points in the higher onset risk group and 6.7 percentage points in the lower-risk group, with their difference statistically significant (p-value = .034). While the difference in ATTs across high- and low-risk groups is 25.6 percentage points among farmers with larger-size farms, it is 14.5 percentage point among farmers with smaller-size farms. Similar results are observed if 3 ha is used as the farm size threshold instead of 2 ha. The results in Table 4.2 therefore support both Hypotheses 1 and 2, suggesting that higher long-term onset risk raises the demand for draft animals, particularly among farmers with larger farm sizes.

The results presented in Table 4.3 provide further evidence of the effects of onset risk. Among the non-decreasing-risk group, the project raised the likelihood of participants investing in draft animals by 18.2 percentage points, and by 10.1 percentage points in states where onset risk decreased. These differences become statistically significant when LGA wage and interaction terms are also included as explanatory variables. The difference is even sharper among farmers with larger-size farms. The ATT is 30.5 percentage points compared to 3.0 percentage points (which is statistically insignificant) among farmers who cultivated 3 ha or more in 2005, and 24.4 percentage points compared to 7.7 percentage points for those who cultivated 2 ha or more; both figures are statistically significantly different across groups. The differences are statistically insignificant among farmers with smaller-size farms. The results in Table 4.3 add stronger support to Hypotheses 1 and 2 by suggesting that not only long-term onset risk but also short-term fluctuations affect farmers' investment in draft animals.

Table 4.3—ATT and changes in onset risk

	All	All (with LGA average wage)	Farm size in previous year (LGA average wage excluded)				p-value (by farm size)
			≥ 3 ha	≥ 2 ha	< 3 ha	< 2 ha	
Increase or no change	.182*** (.043) *296*	.260*** (.054) *199*	.305*** (.109) *122*		.099** (.049) *161*		.085
				.244*** (.066) *171*		.087** (.042) *114*	.045
Decrease	.101*** (.036) *309*	.093*** (.028) *208*	.030 (.030) *65*		.165*** (.050) *214*		.021
				.077** (.037) *119*		.132** (.064) *137*	.457
p-value (by change in onset risk)	.149	.006	.015	.027	.346	.557	

Source: Author.

Notes: Numbers in parentheses are the corresponding standard errors, italic numbers are the corresponding matched sample sizes, and the p-values in the last column and row indicate the statistical significance of the difference between ATTs from different onset risks or farm sizes.

*** Significant at 1%; ** Significant at 5%; * Significant at 10%

The results summarized in Table 4.4 show similar analyses of the effects of change in rainfall risk, which contrast with those in Table 4.3. No significant differences in effects are observed across groups experiencing different rainfall risk changes, even within the subgroups differentiated by farm size, although the effects of projects are statistically significantly positive in both groups. The difference between the figures in Table 4.3 and Table 4.4 suggests that draft animal investment is more responsive to onset risk than to annual rainfall risk and supports the motivation of this study.

Table 4.4—ATT and changes in rainfall risk

	All	All (with LGA average wage)	Farm size in previous year (LGA average wage excluded)				p-value (by farm size)
			≥ 3 ha	≥ 2 ha	< 3 ha	< 2 ha	
Increase or no change	.135*** (.032) *364*	.182*** (.035) *319*	.267*** (.058) *130*		.094** (.040) *194*		.014
				.156*** (.056) *198*		.109*** (.042) *144*	.502
Decrease	.152*** (.042) *237*	.140*** (.053) *99*	.188* (.101) *40*		.171*** (.057) *182*		.883
				.151* (.090) *97*		.154 ** (.062) *133*	.978
p-value (by change in onset risk)	.747	.508	.498	.962	.269	.548	

Source: Author.

Notes: Numbers in parentheses are the corresponding standard errors, italic numbers are the corresponding matched sample sizes, and the p-values in the last column and row indicate the statistical significance of the difference between ATTs from different onset risks or farm sizes.

*** Significant at 1%; ** Significant at 5%; * Significant at 10%

Additionally, we investigated how the project affected the size of cultivated area and how such impacts differed across different onset risk groups. Table 4.5 provides further evidence of potentially different motives for investment in draft animals under different onset risks. In areas with higher, non-decreasing onset risk, the project did not lead to a statistically significant increase in cultivated area. In areas with low or decreasing onset risk, in contrast, the project led to a statistically significant increase in cultivated area, by approximately 0.235 to 0.25 ha. Although the project provides other services beyond support for draft animal investment, such differentiated effects on cultivated area are consistent with the hypothesis that draft animal investment is led by risk-mitigation rather than area-expansion motives in regions with high, non-decreasing onset risk, while in regions with low, decreasing onset risk, it is led more by the area-expansion motive than the risk-mitigation motive.

Table 4.5—Average treatment effect of Fadama project on cultivated area

Group	Change in cultivated area (ha)
High risk	.273 (.294) *347*
Low risk	.250*** (.073) *219*
Non-decreasing risk	.245 (.281) *290*
Decreasing risk	.235*** (.065) *297*

Source: Author.
Notes: Numbers in parentheses are the corresponding standard errors and italic numbers are the corresponding matched sample sizes.
*** Significant at 1%; ** Significant at 5%; * Significant at 10%.

Overall, the results indicate that not only longer-term onset risk but also its short-term fluctuations have significant effects on the investment in draft animals. Moreover, investment in draft animals responds more to changes in onset risk than to changes in rainfall risk. This may be because farmers can more easily recognize the change in onset days than the total rainfall of the year, as few farmers presumably have access to rainfall data. In addition, farmers may be more sensitive and averse to risk associated with planting timing than to rainfall risk over the entire production season. Farmers, particularly those with larger farm sizes, may be able to adjust their production practices somewhat and cope with rainfall risk in later stages. These farmers may, however, still rely on optimal timing for land preparation and planting in order to maximize their crop productivity.

5. CONCLUSIONS

Farmers' investment in productive assets is often driven by risk-mitigating motives. Agriculture in developing countries, in particular, may be subject not only to the uncertainty of total rainfall but also the uncertainty of its timing. Analyzing the patterns of such timing uncertainty and its effect on farmers' investment behaviors can deepen our understanding of how different aspects of risks matter. Onset risk, the uncertainty about the beginning of the rainy season, is particularly important in that regard, and we tested our hypothesis that investment in draft animals is in part driven by farmers' desire to mitigate onset risk, which could otherwise raise the cost of critical farm activities at the beginning of rainy seasons.

We find that long-term onset risk may vary significantly across locations and may also be associated with significant short-term fluctuations in northern and central Nigeria. Various methodologies lead to similar rankings of the locations by risk. For several locations, the short-term increase or decrease in onset risk within the periods can be identified, and these changes are robust to the choice of threshold years.

Farmers in low-income countries may invest in draft animals partly to mitigate the effects of high and non-decreasing onset risk. We find examples from northern and central Nigeria supporting our hypothesis. Farmers' perceptions of onset risk may be affected both by the longer-term trend and by shorter-term fluctuations. Farmers may be more sensitive to short-term fluctuations in onset risk than to short-term fluctuations in rainfall risk, possibly because the former may be more perceptible than the latter if information such as rainfall data is inaccessible. High and increasing onset risk may raise the importance of public support for investment in appropriate productive assets such as draft animals. Although such public support may not be entirely pro-poor, since larger-scale farmers may benefit more than small-scale farmers, improved insurance against onset risk can lead to generally more productive uses of resources in both farming and nonfarming activities in rural areas and can benefit the poor as well in the long run. Close monitoring of onset risk may be valuable and could help identify further sources of risk for farmers even when rainfall risk is small. Therefore, in addition to providing effective risk mitigation support in high-risk areas, informing farmers of the recent trends in onset date variations and their potential effect on productivity may be beneficial. Lastly, the results indicate that demand exists among farmers for insurance against onset risk, which should also inspire further research on potential roles played by index insurance based on the rainy season onset date.

APPENDIX: SERIAL CORRELATION IN ONSET DATES

One way to test the autocorrelation in unbalanced, unequally spaced data, such as our onset date, is to use the locally best invariant (LBI) test proposed by Baltagi and Wu (1999). Table A.1 shows the Baltagi-Wu LBI statistics for all samples as well as samples from each region. Though the critical values for the Baltagi-Wu LBI test vary, other studies generally suggest that Baltagi-Wu LBI statistics exceeding 2 indicate the absence of autocorrelation. As in Table A.1, therefore, onset dates are not significantly autocorrelated.

Table A.1—Test for serial correlation (Baltagi-Wu statistics)

	No. of observations	Baltagi-Wu LBI statistics
All	224	2.215
North	97	2.019
Central	48	2.314
North and Central	145	2.096

Source: Author's calculation.

Notes: North = Bauchi, Kaduna, Sokoto; Central = Abuja, Minna. The Baltagi-Wu test is appropriate for testing serial correlation in unbalanced, unequally spaced panel data. Baltagi-Wu LBI statistics exceeding 2 generally indicate the absence of autocorrelation.

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