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Publication Date

2009-07-01



Center of Evaluation for Global Action
Working Paper Series

Agriculture for Development
Paper No. AfD-0904
Issued in July 2009

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Series Description: The CEGA AfD Working Paper series contains papers presented at the May 2009 Conference on “Agriculture for Development in Sub-Saharan Africa,” sponsored jointly by the African Economic Research Consortium (AERC) and CEGA.

Recommended Citation: Marcel Fafchamps. (2009) Vulnerability, Risk Management, and Agricultural Development. CEGA Working Paper Series No. AfD-0904. Center of Evaluation for Global Action. University of California, Berkeley.

Vulnerability, Risk Management, and Agricultural Development*

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May 2009

1. Introduction

Vulnerability to risk is a dominant feature of the poor's livelihood. This is particularly true for small farmers in developing countries. Shocks affects welfare through the shocks it induces on income, assets, and health. For many poor farmers in developing countries, risk remains a serious cause of poverty and ruin – and in still too many instances a matter of life and death.

Households' desire to protect themselves against shocks is thought to affect their production and savings decisions. This applies in particular to the adoption of agricultural technology. Choosing among crops and techniques of production is like choosing between lotteries, each with its own distribution of anticipated earnings. Farmers who are fearful of future loss of earnings may be reluctant to adopt technological innovations with a variable or unknown return.

This observation forms the basis of much thinking about technology adoption by small farmers in developing countries. Reluctance to adopt new agricultural technology for fear of risk is often seen as a key contributor to the persistence of rural poverty: poor people fear the risk

*This paper was prepared for the AERC Conference on Agriculture and Development held in Mombasa, Kenya, on May 28-30, 2009.

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associated with innovation, and this keeps them poor.

While the argument is intellectually convincing, what remains unclear is how relevant it is in practice. The purpose of this paper is to revisit the literature on the risk management and technology adoption practices of rural households in the developing world. The interaction between risk and poverty has received much attention in the development literature over the last three decades. I have summarized much of it in my 2003 book entitled *Risk, Poverty, and Rural Development*. Here I focus on a number of issues that do not receive much coverage in the book but have emerged as active research areas in recent years.

I start by taking stock of what we know and do not know regarding the behavior of farmers with respect to shocks. I then examine what we know about how risk affects behavior, with a particular emphasis on the behavior of farmers in developing countries. I then turn to the recent literature on technology adoption, with a special focus on findings from field experiments.

2. Shocks

There is no doubt that shocks affect the livelihood of numerous individuals and household across the world. Our primary interest is how the behavior and welfare of poor households is affected by risk. Although the literature sometimes uses the words ‘risk’ and ‘shocks’ interchangeably, the two concepts are quite distinct.

Shocks can affect welfare and behavior even if they were unanticipated, that is, even if people never expected the shock to happen, and took no precaution against it. People often responds to a shock, trying to minimize its adverse effects or maximize its beneficial effects. But this does not imply that their behavior is affected by risk. This happens only if people understand a shock may occur in the future, and somehow adjust their behavior to that possibility. For instance, people may anticipate becoming ill at some point in the future, and this may incite them to

secure health insurance. Or they may anticipate rainfall variations, and adapt their cropping pattern to be resilient to drought. But they may not anticipate being hit by an earthquake, and therefore take no precaution against this possibility.

Much of the empirical literature focuses on the effect of shocks rather than risk. This is understandable. The impact of shocks on outcomes and behavior is relatively easy to demonstrate rigorously, given that most shocks are determined by events beyond the control of individual agents. Consequently, when using shocks as regressors to explain various outcome and behavioral variables, exogeneity is seldom in question, and this facilitates causal inference. In contrast, documenting the effect of risk on behavior is much harder, with the possible exception of laboratory experiments.

There is a voluminous empirical literature documenting the many different ways by which adverse shocks of various kinds can decrease human welfare temporarily or permanently. Rainfall data, for instance, have been extensively used to identify the effect of weather shocks on agricultural yields and incomes (e.g., see Porter (2008), Chapter 4 for a recent example). Other detrimental weather effects have been documented, such as long term effects on school attendance and enrollment (Jacoby and Skoufias 1997), the nutrition and height of children (Alderman, Hoddinott and Kinsey 2006), and their ultimate educational attainment (Portner 2008).

The effect of health shocks are well documented too. The effect of the death of a parent on the future of their children has been studied by a number of authors (e.g. Akresh 2004, Evans 2004, Ksoll 2007). In a similar vein, (Fafchamps and Kebede 2007) document the effect that disability has on income and well-being. Other authors have similarly studied adverse effects resulting from political events and warfare (Miguel and Roland 2006). Crime too has been linked to a reduction in welfare (e.g. Fafchamps and Minten 2004, Fafchamps and Minten 2005).

The literature has extensively studied the beneficial effect of positive shocks, such as the

introduction of a cash transfer (e.g., Progresa) or food-for-work program. Here the emphasis has been on long-term beneficial effects on the education, nutrition, and health of children. In a similar vein, De Mel, McKenzie and Woodruff (2007) document the effect that a cash grant has on microenterprise income and household welfare.

Although this literature clearly demonstrates that positive and negative shocks can have a dramatic impact on current and future human welfare, this does not, by itself, demonstrate that people anticipated these shocks in any way, and anticipatively adjusted their behavior. Put differently, the recent empirical development literature has relatively little to say about the possible effect of risk on behavior.

At first glance this is strange because the theoretical literature on risk has focused primarily if not exclusively on how the prospect of future shocks anticipatively affects behavior. For those interested in farmers, the paper that started it all is Sandmo (1971) 's seminal contribution showing that risk aversion leads to under-investment and underproduction. Other theoretical contributions similarly indicate that, in the absence of insurance markets, risk averse investors would shy away from risky assets and concentrate their portfolio in safe assets, even if their return is lower (Dreze and Modigliani 1972).

Based on these theoretical observations, risk aversion combined with the absence of insurance is often mentioned as a potentially important contributing factor to poverty traps: poor households are predicted to stay away from high return investment opportunities because they fear the consequences of failure. These ideas influenced the development literature of the 1970's and 1980's, for instance inducing Binswanger (1980) to measure risk aversion among ICRISAT farmers in the late 1970's.

3. Risk management theory

Because Sandmo's argument has been so influential, it is worthwhile providing a modern treatment of it. We first illustrate what happens when a market for insurance exists. Consider an expected utility household model of the form:

$$V(Y) = \max_{W,A,N} U(Y - W - A + N) + \beta EV(W(1+r) + \pi(A)\theta - N\gamma\theta) \quad (3.1a)$$

This model can either be seen as a two-period model (as in the original Sandmo paper) or as the Belman equation of an intertemporal model. Y is current income (cash-in-hand), W is saving in a liquid asset with a fixed return r , A is investment in a risky activity $\pi(A)\theta$ where θ is a random shock, and N is the sale of a security that pays a unit return of $\theta\gamma$. We assume that the risky activity has positive but decreasing marginal returns in A : $\pi' > 0$ and $\pi'' < 0$. The return on security N is perfectly correlated with θ and hence with the return from the risky activity. Thus, by selling security N , the household is able to 'sell' the risk from the risky activity at a fixed price $1/\gamma$, thereby shifting as much of the risk θ onto others as it wishes.

The first order conditions are:

$$-U' + \beta E[V'](1+r) = 0 \quad (3.2)$$

$$-U' + \beta E[V'\theta]\pi' = 0 \quad (3.3)$$

$$-U' + \beta E[V'\theta]\gamma = 0 \quad (3.4)$$

Equations (3.3) and (3.4) can easily be manipulated to yield:

$$\pi'(A) = \gamma \quad (3.5)$$

Equation (3.5) implies that the choice of A depends only on the price of the security N . Separability applies: production decisions do not depend on household preferences, including their preferences regarding risk. The model can be amended so that N resembles more closely an insurance contract, with an identical result.

Separability no longer holds if a market for securities or for insurance does not exist. To see this, consider the model without N :

$$\max_{W,A} U(Y - W - A) + \beta EV(W(1 + r) + \pi(A)\theta)$$

The first order conditions are:

$$-U' + \beta E[V'](1 + r) = 0 \tag{3.6}$$

$$-U' + \beta E[V'\theta]\pi' = 0 \tag{3.7}$$

which, after some straightforward manipulation, yields:

$$\pi'(A_a) = (1 + r) \frac{E[V']}{E[V'\theta]} \tag{3.8}$$

where A_a denotes the level of investment of a risk averse household. In the case of a risk neutral household, V is linear and thus V' is constant that factors out. Equation (3.8) then simplifies to:

$$\pi'(A_n)E[\theta] = (1 + r) \tag{3.9}$$

where A_n denotes the level of investment of a risk neutral household. Equation (3.9) implies that the expected marginal return to investment equals the interest rate.

We want to know whether A_a is in general smaller than A_n . We first note that if $\frac{E[V']}{E[V'\theta]} > 1$,

then $\pi'(A_a) > 1 + r$. Since $\pi'' < 0$, this also implies that $A_a < A_n$. In contrast, if $\pi'(A_a) < 1 + r$, then the optimal choice of A_a is above A_n . Whether $A_a \leq A_n$ therefore depends on whether $E[V'\theta] \leq E[V']$.

It can be shown that $E[V'\theta] < E[V']$ when the household is risk averse. To see why, note that $E[V']$ can be regarded as a straight average and $E[V'\theta]$ as a weighted average, where the θ 's are the weights.¹ If the household is risk averse, large values of θ – large incomes – are associated with low values of marginal utility V' . Similarly, low values of θ are associated with high values of V' . This means that in the weighted sum $E[V'\theta]$, high values of V' get a low weight while low values of V' get a high weight. It follows that $E[V'\theta] < E[V']$ and thus that $A_a < A_n$.²

In Sandmo's original treatment of this model, $V(\cdot)$ is taken to represent utility and its curvature is interpreted as risk aversion. As equation (3.1a) illustrates, however, $V(\cdot)$ is better seen as a value function. Its curvature depends not only on the curvature of utility function $U(\cdot)$ – i.e., intrinsic risk preferences – but also on the availability of self-insurance devices, e.g., precautionary savings in the form of liquid assets W . The more W the household holds, the better it can smooth income shocks, and the flatter $V(\cdot)$ is. Access to other forms of

¹This is most easily seen if θ is normalized so that $E[\theta] = 1$; otherwise, divide through by $E[\theta]$ and redefine θ as $\theta/E[\theta]$.

²This can be formalized as follows. To save on notation, write $V'(W(1+r) + \pi(A)\theta)$ more compactly as $V'(\theta)$. We have:

$$\begin{aligned} V'(\theta) &> V'(E[\theta]) \text{ if } \theta < E[\theta] \\ V'(\theta) &< V'(E[\theta]) \text{ if } \theta > E[\theta] \end{aligned}$$

Consequently, we may write:

$$V'(\theta)(\theta - E[\theta]) \leq V'(E[\theta])(\theta - E[\theta]) \text{ for all } \theta$$

Since this is true for all θ , it is also true on average. Taking expectations, we have:

$$\begin{aligned} E[V'(\theta)(\theta - E[\theta])] &\leq E[V'(E[\theta])(\theta - E[\theta])] \\ E[V'(\theta)\theta] - E[V'(\theta)]E[\theta] &\leq V'(E[\theta])(E[\theta] - E[\theta]) = 0 \end{aligned}$$

which leads to:

$$E[V'(\theta)\theta] \leq E[V'(\theta)]E[\theta]$$

as claimed.

insurance, however imperfect, will also flatten $V(\cdot)$, making farming decisions less sensitive to risk, and under-investment less serious. These findings have been subsequently extended in various directions (Newbery and Stiglitz 1981). Kimball (1990) in particular has shown that a monotonic relationship exists between investment decisions A_a and prudence, defined as V'''/V'' .

We have thus established that $A_a < A_n$ – there is under-investment – if the decision maker is risk averse and does not have access to insurance. This result has been and still is very influential. It has been used extensively as possible explanation of why poor households refrain from investing in (more risky) new technology. The question is whether this insight is empirically relevant.

4. Evidence on risk and risk taking

Unfortunately, we do not have a lot of hard evidence that risk is the main obstacle to the adoption of new technology by poor farmers in the developing world. As mentioned earlier, this issue attracted some attention in the 1970's and 1980's. But by the 1990's the research emphasis had shifted to risk coping strategies involving precautionary saving and mutual insurance. One possible explanation for this turn of events was that the exogeneity of many shocks (e.g., rainfall, illness) provides an easy identification strategy to draw causal inference regarding the effect of shocks on transfers, asset sales, or savings. Analyzing the effect of risk on risk taking by farmers in developing countries is harder to do.

4.1. Econometric evidence

It is empirically difficult to formally test theories that relate decisions made by poor households with the relative riskiness of the options available to them. There two main reasons for this. First, it is very difficult to obtain measurable variation in risk across individuals. The reason

is that, by definition, risk materializes over time. Consequently, a lot of information is required to construct reasonable measures of risk. Secondly, even when measures of riskiness can be constructed, sufficient exogenous variation in risk must be available to distinguish what can reasonably be attributed to risk as opposed to other features typically correlated with risk. For instance, different agro-climatic regions have different crop-specific risk levels. But they also differ in many other respects, not least the profitability of different crops or activities. Given this, it is difficult to ascribe a causal interpretation to empirical regularities, even if they can be shown to be present.

This probably explains why there is very little research on the effect of risk on behavior among rural households in developing countries. Using survey data from Pakistani farmers involved in dairy production, Kurosaki and Fafchamps (2002) show that observed cropping patterns are consistent with farmers' desire to cover their fodder production needs to reduce exposure to input price risk. In this paper, risk measures are constructed by combining longitudinal price data with cross-section yield variation. The effect of risk on decisions is estimated using a structural model that allows for risk averse preferences.

Using panel household data on rural Ethiopia, Rogg (2005) shows that the asset holdings and portfolio mix of rural households is correlated with relative riskiness in a way that is consistent with theory. Hill (2005) shows that more risk averse Ugandan farmers were less likely to replant coffee trees, given the risk represented by the coffee wilt disease. In a different vein, Portner (2008) uses historical data on hurricane incidence in Honduras to construct a measure of location-specific hurricane risk. The author then uses this risk measure to estimate the effect of risk on education decisions. He shows that locations with a higher risk of hurricane invest more in education, even though hurricane events themselves have a negative effect on education. Portner interpret these results as suggesting that households invest in education so as to be better able

to escape the worst consequences of future hurricanes.

Though valiant, all these studies suffer from the need to make some assumptions to achieve identification. In particular, they have to make assumptions about the absence of omitted variable bias – e.g., the risk measure is not capturing something else – and about possible endogenous placement – e.g., risk averse individuals may have left areas more affected by risk.

Other authors have sought to simulate the anticipated gain from risk reduction. If risk aversion explains farmers' reluctance to adopt new technologies, it should be that the prospect for risk reduction is large. Using detailed data on ICRISAT farmers in India, Walker and Ryan (1990) estimate the welfare gain that would be induced by a complete elimination of millet yield risk. They find that the equivalent variation of the complete elimination of such risk is only a small proportion of total income. One may argue that these findings come from the fact that millet is a drought-resistant crop with low variance, so perhaps they may not be representative of the risk reduction achieved by avoiding drought-vulnerable crops. What the Walker and Ryan simulation illustrates, however, is that farmers grow different crops and in general have diversified sources of income, so that risk associated with a single crop need not make a large contribution to total income risk.

Health shocks, in contrast, may be of more importance because they affect the household's ability to produce and generate income. Fafchamps and Lund (2003) and De Weerd and Fafchamps (2007) indeed find that transfers and informal loans respond to health shocks.

4.2. Circumstantial evidence

While rigorous empirical evidence on the relationship between risk and risk taking is hard to find for rural households in developing countries, there is ample circumstantial evidence that the Sandmo model is not consistent with farmers' behavior. First of all, farmers by definition

engage in activities that carry a lot of risk. So they do not appear to shy away from risk.

Existing theory suggests that farmers are more likely to engage in risky activities if they are well insured. Is this the case? Not really. Government-sponsored safety nets for rural dwellers remain conspicuous by their absence. Although many examples have been found of informal and semi-formal insurance mechanisms operating in poor rural communities, the evidence also shows that these mechanisms nearly never provide adequate protection against shocks (e.g. Rosenzweig 1988, Townsend 1994, Fafchamps and Lund 2003). It is therefore very unlikely that the reason why small farmers engage in risk activities is because they are well insured.

Could it be then that they have sufficient liquid assets to self-insure? There is indeed ample evidence that rural households across the developing world accumulate savings or liquid assets as a form of precautionary savings (e.g. Deaton 1992, Deaton 1991). But these assets are seldom sufficient to smooth consumption. Fafchamps, Udry and Czukas (1998) and Kazianga and Udry (2004), for instance, show that Burkina Faso rural households affected by the 1984 drought refrained from selling cattle and opted to reduce consumption instead – and may have incurred excess mortality as a result. The reason offered for this result is that farmers fear losing productive assets. Distress sale of land or cattle appears to be seen with great reluctance by many rural households: it may solve an immediate scarcity problem, but it would lead to more severe poverty in the future, a point formalized for instance in Carter and Zimmerman (2000). Lybbert, Barrett, Desta and Coppock (2000) revisit this issue in the context of East African pastoralists, showing that herders who have too few animals to sustain themselves during transhumance cannot maintain a pastoralist lifestyle – and face a much higher probability of losing all their livestock.

What these two examples suggest is that poor farmers deal with risk in ways that appear different from those suggested by Sandmo's model. In Burkina Faso, farmers prefer to reduce

consumption rather than sell cattle. In East Africa, pastoralists prefer to hold onto their animals to preserve their lifestyle. In both cases, households appear remarkably willing to ‘toughen it up’, that is, to face up to the consequences of risk. Of course their choices are severely limited, but the evidence does not seem to indicate that poor farmers shy away from risky activities.

There is another reason why Sandmo’s model is a poor candidate to explain resistance to innovation. Much agricultural technology is divisible. This is particularly true for much Green Revolution type technology, such as improved seeds, chemical fertilizer, and pesticides. This dramatically reduces the risk associated with farmer experimentation since it is fairly easy to try out a new technology on a small scale before adopting it on the whole farm. Yet agricultural surveys provide little evidence of small scale experimentation by farmers in developing countries. Partial adoption of a new crop or technology would also make sense from a diversification point of view: even though a new crop or technology may be more risky than an existing one, combining both may nevertheless reduce risk relative to the old technology alone. For this reason, one would expect risk averse farmers to keenly adopt new divisible technologies, but only partially. Yet farmers often seem to switch entirely to a new technique of production, even though they may subsequently revert to the old technology if the outcome was unsatisfactory. This kind of behavior is difficult to reconcile with the idea that farmers seek to minimize risk.

Sub-Saharan African is often mentioned as a place where farmers have been very reluctant to the introduction of new agricultural practices. This is often taken as a reason for the poor agricultural performance of the continent. Yet such claims fail to acknowledge that African agriculture has dramatically changed over the last century or so. Perhaps the most obvious and the most far reaching change has been the introduction of new crops – maize, rice, sweet potatoes, cassava, tomato, potato, to name but a few. These crops have spread massively over the last two decades, with some government support.

New cash crops have also emerged that are grown by small farmers, either for export or for local urban markets. This is true for Africa – e.g., pineapple, green beans, onion (e.g. Jaffee and Morton 1995, Conley and Udry 2001). It is even more true for India where an agriculture traditionally centered on staple foods is rapidly moving towards horticulture and the production of high risk/high return crops. External intervention has often been instrumental in fostering these changes, primarily in terms of marketing and input distribution (e.g. Conning 2001, Bandiera and Rasul 2006, Ashaf, Gine and Karlan 2006). But adoption has been locally widespread even though these crops often are quite risky, with volatile prices and variable yields. Based on these experiences, risk aversion does not appear to have been the impediment to agricultural innovation that it was once thought to be. There seems to be little value to the idea that risk aversion pulls poor agricultural households away from decisions that would, in time, make them more prosperous. Risk aversion appears a poor candidate to explain persistent rural poverty.

5. Adoption of agricultural innovations

5.1. Input delivery mechanisms

There nevertheless remain a number of puzzles that continue to defy explanation. If farmers are not risk averse in the Sandmo sense, how can we explain that decentralized market forces seem to have a difficult time delivering agricultural inputs to poor farmers in developing countries. Successful input distribution schemes appear to combine two key features: they provide inputs on credit; and they eliminate ‘out-of-pocket risk’ without eliminating upside risk, that is, they are designed in such a way that the farmer pays for inputs only if the crop is successful.

The first and most enduring example of an input delivery scheme that shares these features is sharecropping. In a sharecropping contract, a farmer pays for land with a portion of the harvest

produced by that land. While up-front payment can be requested for fixed rental contracts, this is not possible for sharecropping contracts since payment can only be assessed after harvest. This means that land is de facto given on credit. It is also common for the landlord to provide other inputs on credit (e.g. Braverman and Stiglitz 1986, Shaban 1987, Dubois 2000, Jacoby, Murgai and Rehman 2002). Sharecropping therefore provides farmers with agricultural inputs on credit. Furthermore, it eliminates bankruptcy risk: if the crop fails, nothing is paid.³ In spite of initial fears regarding landlords' willingness to invest in new technology (Bhaduri 1973), the bulk of the evidence now indicates that sharecropping is an effective way of delivering input credit to producers (e.g. Braverman and Stiglitz 1986, Gavian and Teklu 1996, Jacoby et al. 2002).

The second example is taken from the input delivery practices of agricultural marketing boards during and after the colonial period in Sub-Saharan Africa.⁴ It was common practice for agricultural marketing board to provide farmers with agricultural inputs at the beginning of the season and to recoup the cost of these inputs at harvest time. Since many of these marketing boards had a monopsony on the cash crop they were responsible for, producers could not abscond from the credit they had received by selling to someone else.⁵ This method of recouping input credit through monopsony means that farmers are responsible for input costs only up to the value of their cash crop output. The method by which this is accomplished varies (sometimes input costs are simply deducted from a pan-territorial output price, sometimes villagers as a group are held collectively responsible for the payment of inputs used in their village). But the end result is the same: in case of crop failure, producers pay nothing.

The third example comes from contract farming. In many ways, contract farming resembles what agricultural marketing boards do: they provide affiliated growers with seeds and inputs

³In fact, there is evidence that even when harvest is poor although not zero, tenants are also dispensed to share output with the landlord (e.g. Singh 1989, Dutta, Ray and Sengupta 1989).

⁴Cotton marketing boards in West Africa are a good illustration of these practices (?).

⁵Although some invariably tried, especially nearby porous borders like that between Senegal and Gambia.

and promise to purchase all or part of their output, at which time inputs costs are deducted from the output price. The crop itself serves as collateral for the inputs and the contractor often has the right to harvest the crop to recoup the cost of the inputs.⁶ Although in theory contractors could seek to recover all input costs on growers' assets in case of crop failure, they hesitate to do so not to antagonize their growers. So, *de facto*, growers pay nothing in case of crop failure.

These three input delivery schemes have two features in common: payment at harvest, and no payment in case of crop failure. Otherwise the details of input repayment vary a lot from one example to the next – in the sharecropping example, costs are paid as a share of harvest; in the agricultural marketing board example, costs are deducted from the output price or paid jointly by villagers; in contract farming, costs are deducted from the value of the harvested crop. This much variation suggests that these contractual details are less important than the two principles listed above. Similar principles can be successfully applied to other technology delivery schemes, such as animal traction equipment.⁷

In my book on risk and rural development, I offer a simple extension of the Sandmo model which can account for these observations. Farmers are assumed to worry about out-of-pocket risk: they do not like to finish the year in the red. The addition of this simple assumption is sufficient to account for the success of the above-mentioned schemes even if farmers are otherwise risk neutral (or even risk loving). This is important because we have argued earlier in this paper that the expected utility framework – which assumes aversion to upside as well as downside risk – may not be a very convincing.

The question then is: why is assuming aversion to out-of-pocket risk any more reasonable than assuming risk aversion in an expected utility framework? Here behavioral economics comes

⁶In fact, certain contracts stipulate that harvesting is done by the contractor itself.

⁷In this case, repayment of the equipment is spread over several years and producers get a repayment holiday if they can show they were hit by an adverse shock (ILO 1984).

to the rescue.

5.2. Field experiments and behavioral economics

Ever since Binswanger's (1980) early work on risk aversion among ICRISAT farmers, researchers working on agricultural technology issues have been aware of experimental economics. But they may not have taken advantage of all its lessons.

Results from laboratory experiments have long suggested that what humans fear is not risk but the prospect of loss (Tversky 1991). This is most easily demonstrated by experiments in which participants are asked to choose among lotteries with identical final payoffs, but a different sequence of events. While participants often are willing to gamble for future gain, they are less willing to put earlier winnings at risk, even if final payoffs are identically distributed. This could explain why farmers are not willing to put assets at risk by buying agricultural inputs they are not guaranteed to recoup. By eliminating downside risk, the input delivery contracts discussed earlier do not remove upside risk but they deal with loss aversion.

Laboratory experiments have also shown that humans have a poor intuitive understanding of low probability events. For instance, it is common for participants to experiments to be willing to pay the same for a risk reduction of one in a thousand or one in a million – even though the former should be worth one thousand times more than the latter. People are sensitive to whether they have recently been affected by similar events and can recall similar incidents. Indeed recent exposure to low probability events tend to dramatically raise people's willingness to pay to protect themselves against the future recurrence of similar events. It follows that people respond to how the risk of future events is framed, and whether they can recognize past experiences in experimental situations. Finally people may be quite averse to small probability events that are beyond their control (e.g., a plane crash) but not overly worried by high(er)

probability events they perceive to be under their control (e.g., a motorbike accident). Taken together, this evidence suggests that people are actually not very rational when it comes to small risks, but also that they are weary of downside risk beyond their control.

Experiments further suggest that people may be overly optimistic when it comes to upside risk. People often overestimate their chances in risky ventures. As a result, they often want to overinvest, provided they are sheltered from downside risk. This may explain why many entrepreneurs whose honesty is not in question seem keen to invest uncollateralized borrowed funds in risky projects. Such findings are in line with our earlier observation regarding the relative success of agricultural input delivery schemes that protect farmers from downside risk but expose them to considerable upside risk.

Taken together, these empirical regularities documented in laboratory experiments may help explain observed patterns of agricultural technology adoption. Recent field experiments add new insights to this body of knowledge. Of particular interest to our purpose is a recent paper by Duflo (2006) on fertilizer adoption in Kenya. At the end of the paper, the authors document a series of field experiment investigating the effect of fertilizer vouchers on input usage. They find much higher fertilizer usage among farmers who were offered a voucher for future fertilizer delivery at the time of selling their crop. This finding is broadly in line with experimental findings about quasi-hyperbolic preferences, forced savings contracts, and people's desire to commit future expenditures (Ashraf, Karlan and Yin 2006).

Duflo (2006) investigate possible explanations for their finding. Of interest is the observation that fertilizer usage drops significantly if the voucher is sold to farmers only a day or two after they sell their crop. Why this is the case is not entirely clear, however. One possibility is that the money has already found other uses, e.g., paying for debts and social obligations. Another possibility is reciprocity: when the voucher is sold by the buyer of the crop, the seller may

feel some sense of obligation to reciprocate by purchasing a fertilizer voucher. More work is underway to disentangle these possible explanations. What they do suggest, however, is that input usage by small farmers in developing countries may be quite sensitive to the method of delivery and sale. Rational models of input purchases are not vindicated as there are strange behavioral responses to commitment devices offered to input purchasers.

Peer effects may also matter. Ashaf et al. (2006) document an outgrower scheme run by an NGO in Kenya. The authors evaluate a program in Kenya that encourages the production of export oriented crops by providing smallholder farmers with credit linked to agricultural extension and marketing services. They use an experimental design in which farmer self-help groups are randomly assigned to either a control group, a group receiving all DrumNet services, or a group receiving all services except credit. Among the services offered by DrumNet, credit is the most important, a finding that is consistent with the significant investment in capital and inputs required to produce the export crop. This result is also consistent with our earlier observation regarding downside risk.

These results are to be compared to field experiments that offer crop insurance to small farmers. If Sandmo's model is a fair representation of small farmers' decision process, offering insurance corrects a market failure and is the preferred way to achieve first best. Two separate teams of researchers have experimented with crop insurance in two Indian states. Their results are summarized in a jointly authored paper (Cole, Gine, Tobacman, Topalova, Townsend and Vickery 2009). Both field experiments have in common the offer of a voluntary insurance contract that compensates farmers in case of deficient rainfall. Payment is based on objectively collected rainfall data. Farmers purchase insurance in discrete units, with each unit equivalent to set payments conditional on rainfall. Farmers can obtain more insurance by buying more units.

The modeling framework presented in Section 2 predicts that more risk averse farmers should

purchase more insurance than risk neutral farmers. We also argued that the curvature of the value function $V(\cdot)$ depends on the household's capacity to self-insure through the accumulation of liquid assets. This implies that households with more assets need – and should purchase – less insurance. Since small Indian farmers are often poor, we would therefore expect widespread adoption, with many farmers purchasing enough insurance to protect themselves against much of rainfall risk.

This is not what the authors find. Take-up is limited – in the Gujarat experiment, only 20% of targeted farmers purchased the insurance – but sensitive to price and additional marketing. Although results from the two experiments differ somewhat, risk averse households appear less, not more, likely to purchase insurance. Households do not purchase full coverage; on the contrary, they tend to purchase only one unit of insurance, no matter how large their risk exposure. Furthermore, insurance take-up is higher among wealthy households. None of these results are consistent with the standard Sandmo model. The authors also report that take-up is lower among households that are credit constrained. They argue that these results match predictions of an extended Sandmo model with borrowing constraints. Alternative explanations exist as well, such as lack of familiarity with the insurance product.

Other patterns are more difficult to reconcile with the benchmark model. Participation in village networks and measures of familiarity with the insurance vendor are strongly correlated with insurance take-up decisions. While education does not seem to matter, endorsement from a trusted third party does. These results may reflect uncertainty about the product itself, given households' limited experience with it. They are to be compared with those reported by Ashaf et al. (2006) on the role of farmer groups, and to those of Duflo (2006) regarding the possible 'reciprocity' between farmers and crop buyers/input providers.

Gine, Yang, Insurance and from Malawi (2007) report on another similar field experiment

in Malawi. They implement a randomized field experiment to ask whether the provision of insurance against a major source of production risk induces farmers to take out loans to invest in a new crop variety. The study sample was composed of roughly 800 maize and groundnut farmers. The dominant source of production risk is the level of rainfall. The authors randomly select half of the farmers to be offered credit to purchase high-yielding hybrid maize and improved groundnut seeds. The other half are offered a similar credit package but required to purchase (at actuarially fair rates) a weather insurance policy that partially or fully forgives the loan in the event of poor rainfall. If, as we have argued earlier, farmers are primarily concerned about the downside risk associated with credit, offering the insurance should boost take-up. Surprisingly, the authors find that take up is lower by 13 % among farmers offered insurance with the loan. At prima facie, this seems to reject downside risk concerns as the primary motive for low take-up of agricultural innovations. The authors however find suggestive evidence that the reduced take-up of the insured loan is due to the high cognitive cost of evaluating the insurance: the take-up of insured loans is positively correlated with farmer education levels, but not so for uninsured loan.

This brings up another consideration, namely, that people have a complicated relationship with new products. Curiosity may tempt them into trying new products, but such impulse purchases may ultimately prove disappointing. People may therefore steel themselves against large impulse purchases, especially if they are poor. This would be consistent with richer Indian farmers purchasing rainfall insurance, but only one unit, while poorer farmers do not purchase any. People's ability to resist impulse purchases may be susceptible to manipulation by marketing efforts. This may explain why fertilizer vouchers in Kenya found more buyers when the purchase of the voucher was combined with the sale of the crop.

Given this, adoption of new products may require reinforcement from peers: if others around

them are adopting a new product, people may find it harder to resist buying it. This naturally generates threshold effects in adoption, an observation made a long time ago by Griliches (1988). In his study of US farmers, Young and Burke (2001) similarly noted the importance of peer effects and conformity in the adoption of certain types of behavior. The emerging economic literature on social network effects has revived interest in diffusion and reinforcement effects. There is extensive circumstantial evidence that social networks matter for the adoption of agricultural technological and institutional innovations in developing countries (e.g. Foster and Rosenzweig 1995, Conley and Udry 2001, Bandiera and Rasul 2006). In a recent unpublished paper, Caria (2009) argues that Ghanaian farmers who are more risk averse are less likely to experiment with new technology. This may explain why risk averse farmers in Caria's study look up to risk neutral neighbors for advice on new technology.

Taken together, these field experiments suggest that input usage and the purchase of crop insurance are not well accounted for by the standard model presented in Section 2. While an extended model that includes credit constraints and downside risk considerations can explain some of the empirical regularities, other results indicate that subtle psychological manipulations affect take-up. Economic models of rational self-interested but risk averse agents seem unable to predict the adoption of technological (e.g., inputs) and institutional (e.g., insurance) innovations by small farmers in developing countries. The study of agricultural innovation in such communities may benefit from drawing more intensively from the psychological and experimental literature – and even perhaps from the marketing literature.

5.3. Conclusion

The paper has examined the relationship between agricultural development, vulnerability to shocks, and the risk management practices of small farmers in developing countries. A cor-

rect understanding of this relationship is essential to policy makers interested in fostering the introduction of technological and institutional innovations.

For many years, economic thinking on technology adoption has been influenced by a model of a rational but risk averse farmer. This model predicts that risk aversion is a major impediment to the adoption of any innovation that increases risk, either directly (through increased yield risk, or through increased variance of revenues net of input costs) or indirectly (through uncertainty regarding the true return from the innovation).

A first best solution to this problem is the provision of insurance, a solution that until recently was thought impractical for small farmers in developing countries. An alternative solution is the provision of safe savings vehicles to facilitate precautionary savings and self-insurance – thereby reducing the curvature of value function $V(\cdot)$. Agricultural extension may also be required to reduce uncertainty regarding the true return from the proposed innovation.

A version of this model extended to include credit constraints is capable of explaining some of the empirical findings. But successful input delivery systems provide circumstantial evidence that downside risk concerns may explain farmer behavior better. This finding is consistent with experimental evidence emphasizing that loss aversion is a better representation of human preferences than risk aversion.

Recent field experiments indicate that other behavioral considerations play a role as well, such as impulse purchases and vulnerability to marketing efforts, whether well-meaning or not. Some field evidence suggests that small farmers may resist adopting new products not so much because they are resistant to change, but rather because they do not trust themselves not to succumb to impulse purchases. This may explain why adoption of agricultural innovations is often gradual and displays patterns consistent with peer effects through social networks and geographical proximity.

The literature on technology adoption in developing countries started with the view that farmers were irrational and subject to fads and fashions. This patronizing view was then abandoned entirely, to be replaced by a model of rational but constrained decision makers. The literature appears to have come back full circle, with a growing interest in behavioral considerations such as loss aversion, quasi-hyperbolic preferences, impulse purchases, and peer effects. This does not mean that rational behavior has been set aside entirely, but rather that the adoption of new agricultural inputs and practices is now viewed as a combination of rational and behavioral motives. Peer effects also appear more important as improved theoretical and econometric tools to study social networks have breathed new life in the study of reinforcement and diffusion effects in the adoption of agricultural innovations.

After a long period of limited interest in research on the adoption of agricultural innovation, the literature seems to have rediscovered the topic, bringing new tools and renewed energy to the endeavor. Field experiments have brought to light the fact that standard models have a limited predictive power, opening the door to the testing of many alternative and competing explanations. Much work is needed before we reach a new consensus on what motivates technology adoption in poor rural areas.

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