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1. Introduction

Households in developing countries face significant weather-related risks, including drought, flood, tidal waves and hurricanes. Exposure to extreme weather events is likely to increase over future decades, due to climate change as well as population growth in risk-sensitive areas.\(^1\) In recent years, a range of initiatives have sought to develop insurance products to help rural households to mitigate exposure to weather risk. For example, a World Bank (2005a) volume examines ten insurance case studies in countries as diverse as India, Malawi, Nicaragua, and Ukraine. Each case study describes an index insurance product, an insurance contract whose payouts are linked to a publicly observable index such as rainfall recorded on a local rain gauge.

Since 2004 we have conducted household surveys and field experiments in the Indian state of Andhra Pradesh to study household participation in a particular example of index insurance, a rainfall insurance product designed and underwritten by the Indian general insurer ICICI Lombard. The insurance provides cash payouts based on measured cumulative rainfall during different phases of the primary monsoon season. A contract for a single phase of the monsoon costs approximately Rs. 100 (about US $2.50), making the insurance accessible even to relatively poor households.

A significant advantage of the insurance design is that, since payouts are based on measured rainfall, they can be calculated and disbursed quickly and automatically without the need for households to formally file a claim. This in turn reduces transaction costs, which would otherwise tend to drive up the price of the insurance. Fast payouts are also likely to be valued by policyholders in an environment where households are poor and often liquidity-constrained. A second advantage is that the product is free of adverse selection and moral hazard problems that often plague insurance markets. This is because payouts are based only on publicly observed data, rather than private information reported by the person filing claims.

Against these benefits, an important concern in product design is minimizing basis risk, given that measured rainfall is a noisy measure of the quality of the monsoon, from the perspective of crop yields or income for the farmer. Crop yields in semi-arid regions like Andhra Pradesh depend on measured rainfall in complex ways that depends on soil moisture, evaporation, soil type, water runoff and a variety of other

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\(^1\) For example, see Balk et. al., (2009), who use satellite mapping techniques to document population growth in areas subject to climate change and natural disasters.
factors. A variety of other factors may also discourage participation, such as household credit constraints, limited understanding of the product amongst potential consumers, limited trust in the insurance provider, or simply high transaction costs that prevent ICICI Lombard and its local sales partners to offer the insurance at a low enough price relative to expected payouts to make it attractive to consumers.

In the remainder of this chapter, we provide a description of the rainfall insurance contracts offered to households in our study areas, and present a non-technical summary of our main research findings to date. Our research has studied the factors influencing household demand for the product, their understanding of the product, as well as the statistical properties of the insurance contracts, such as the expected frequency and actuarial value of payouts. We also discuss future prospects and challenges for rainfall insurance markets in developing countries.

Our discussion is based on our ongoing academic research, which includes joint research with Shawn Cole (Harvard Business School), Jeremy Tobacman (Wharton School of the University of Pennsylvania) and Petia Topolova (International Monetary Fund). Interested readers are directed to three completed research papers on this topic, which are listed in the references section, for more technical details of our research methodology and findings. For their insights, we gratefully acknowledge our interactions with our co-authors listed above. We also owe a particular debt to Dr K.P.C. Rao, from ICRISAT, the head of our Indian survey and field research team, for his expertise, experience and wisdom, and to the rest of the ICRISAT team.

2. Product design and institutional background
In India, retail rainfall insurance contracts were first developed by the general insurer ICICI Lombard, with technical assistance from the World Bank. The insurance products were piloted in the Ananthapur and Mahbubnagar districts of the state of Andhra Pradesh, a semi-arid region in south-central India. These pilot areas are also the study area for our field research, which has involved a series of household surveys and field experiments conducted since 2004. Over time, rainfall insurance has become more available across many parts of India, although the total amount of retail rainfall insurance written each year remains relatively low.

ICICI Lombard and other Indian rainfall insurance underwriters do not generally sell insurance policies directly to farmers. Instead they partner with local financial institutions in each rural area, which have well-established networks for the provision of financial services to rural households. In our study areas, product marketing and distribution is performed by BASIX, a large microfinance institution. In areas where it is active, BASIX has a network of local agents, known as Livelihood Services Agents (or LSAs) who market a range of credit, savings and insurance products to rural households. (See Cole and Tufano, 2007, for a discussion of the business environment facing BASIX.)
Policies cover rainfall during the primary monsoon season, or “Kharif”, which is the prime cropping season running from approximately June to September. Before each monsoon season, ICICI Lombard designs a set of rainfall insurance contracts, each linked to cumulative rainfall at an individual rain gauge in the relevant rural area. These are then marketed to households by BASIX, who receives a commission for each sale to cover marketing costs and payout disbursements. At the end of the monsoon, ICICI Lombard calculates payouts based on measured rainfall at each rain gauge, and provides funds to BASIX. BASIX then distributes payouts to households through their LSA network, such as by setting up a meeting or collection station in each village to distribute payouts once they become available.

2.1 Contract features

This section describes the design of the rainfall insurance contracts in more detail. For purposes of calculating payouts, the Kharif is divided into three contiguous, sequential phases, each 35-45 days in length, intended to correspond to the agricultural phases of sowing, vegetative growth and harvest. Insurance payouts in the first two phases are linked to deficient rainfall; that is, the policy provides a positive payout if rainfall during the phase is below a particular threshold or ‘strike’ level. In the third phase, corresponding to harvest, this is reversed; the insurance provides a high payout if rainfall is higher than the threshold. This is meant to protect farmers against heavy rains causing damage to mature crops.

For each phase, the underlying index variable used to calculate payouts is accumulated rainfall between the start date and end date of the phase, measured at a nearby reference weather station or rain gauge. The start of the first phase, rather than being a fixed calendar date, is set based on the monsoon rains. Namely, it begins on the first date on which accumulated rain since June 1 exceeds 50mm, or on July 1 if accumulated rain since June 1 is below 50mm.

As an example, consider the contract linked to rainfall in phase 2 of the 2006 monsoon, measured at the Narayanpet Indian Meterological Department (IMD) weather station. This structure of this contract is presented in Figure 1 below [source: Cole et. al., (2009)]. Although contracts differ, the basic structure shown in Figure 1 is broadly representative of the contracts underwritten by ICICI Lombard. As the Figure shows, the policy pays zero if accumulated rainfall during the phase exceeds an upper threshold, or ‘strike’, which in this case is 100mm. Otherwise, the policy pays Rs. 15 for each mm of rainfall deficiency relative to the strike, until the lower threshold, or ‘exit’, is reached. If rainfall is below

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2 Some adjustments are made to accumulated rainfall when constructing the rainfall index used to calculate payouts. If daily rainfall exceeds 60mm, only 60mm is counted towards the cumulative rainfall index. Also, rainfall <2mm is ignored. These adjustments reflect that heavy rain may generate water runoff, resulting in a less than proportionate increase in soil moisture, while very light rain is likely to evaporate before it soaks into the soil.

3 Depending on the policy, the reference weather station is one of three types: an Indian Meteorological Department (IMD) station, mandal rainfall station (a mandal is a local geographic area roughly equivalent to a U.S. county) or one of a network of automated rain gauges installed by ICICI Lombard. For this article, we focus on IMD rainfall data. These are considered to be more reliable than data from mandal stations, and include a longer and more complete history of past rainfall to construct a putative dataset of insurance payouts.
the exit value, the policy pays a fixed, higher indemnity of Rs. 2000. This exit level is meant to approximately correspond to crop failure.

Figure 1: Payout structure: Narayanpet Phase 2 insurance contract

This example is for insurance on a single segment of the monsoon, in this case the second phase, corresponding to vegetative growth. In general, households may choose to purchase policies for an individual phase of the monsoon, or a single policy covering all three phases.

Rainfall index contracts offered by other underwriters may be somewhat different. For example, Cole et. al., (2009) discusses insurance underwritten by a different financial institution, IFFCO-TOKIO, which has a simpler structure covering cumulative rainfall over the entire monsoon.

2.2 Distribution of payouts

In a previous paper, Giné, Townsend and Vickery (2007), we use approximately 30 years of daily historical rainfall data to estimate a putative distribution of insurance returns, based on 11 different contracts offered to farmers in Andhra Pradesh in 2006. Namely, we estimate payouts for each year of our rainfall data, assuming the 2006 contracts had been available during that year.

The estimated distribution of returns is presented in Figure 2 below. The x-axis for the graph is ‘payout rank,’ which ranks payouts in increasing order of size, expressed on a scale from 0 to 1. Figure 2 plots payout amount against payout rank. The calculated distribution presented in the Figure suggests that returns on the rainfall insurance are highly skewed. The payout is zero up to the 89th percentile, indicating
that an indemnity is paid in only 11 percent of phases. The 95th percentile of payouts is around Rs. 200. In about 1% of phases, the insurance pays an indemnity of Rs. 1000, which is the maximum payout for each of these 11 contracts. Thus, ICICI Lombard policies appear primarily to insure against extreme tail events of the rainfall distribution. Confirming this graphical evidence, we calculate that around one-half of the value of indemnities is generated by the highest-paying 2 percent of phases.

Giné, Townsend and Vickery (2007) also calculates the ratio of expected payouts on rainfall insurance relative to premia. We estimate that this ratio is around 30% on average across the 11 weather stations. This relatively low payout rate likely reflects a number of factors, amongst them a lack of economies of scale given the small initial market for the product, and limited competition amongst insurance providers. Payout ratios would likely converge to a higher value in a mature market.

In addition, Cole et. al. (2009) estimates using a simple theoretical model calibrated to empirical estimates that the insurance may still be valuable to Indian households even at a payout ratio of 30%, due to the high sensitivity of agricultural income to variation in the monsoon.

Figure 2: Estimated distribution of insurance payouts

![Graph of insurance payouts](image)

3. Consumer demand for rainfall insurance

Although government crop insurance has been available for a significant period of time, it is mostly compulsory because government bank clients in many states are required to purchase the insurance when borrowing for agricultural purposes. As a result, most borrowers remain uninformed as they perceive the
premium is as a fee. Thus, the provision of explicit market-based rainfall insurance to Indian households remains a new and relatively untested concept. Table 1 below presents some basic information about the growth in rainfall insurance contracts in Andhra Pradesh. The table shows the aggregate number of policies purchased between 2003 and 2006, including the total number of contracts sold and the number of villages where rainfall insurance is available. (This data was made available to us by BASIX from their administrative records.)

Table 1: Rainfall insurance purchases: Andhra Pradesh

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of villages where insurance is sold</th>
<th>Total number of contracts</th>
<th>Contracts per village</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>17</td>
<td>194</td>
<td>11.4</td>
</tr>
<tr>
<td>2004</td>
<td>43</td>
<td>318</td>
<td>7.4</td>
</tr>
<tr>
<td>2005</td>
<td>422</td>
<td>3214</td>
<td>7.6</td>
</tr>
<tr>
<td>2006</td>
<td>538</td>
<td>6039</td>
<td>11.2</td>
</tr>
</tbody>
</table>

Source: BASIX, also cited in Cole et. al. (2009).

Table 1 demonstrates that the number of villages where insurance is available has expanded substantially since the initial 2003 pilot surveys. However the product penetration as measured by the number of policies sold per village where available has remained relatively constant. In 2006 we estimate that one contract is sold for every 13.2 households in villages where rainfall insurance contracts are available. An insurance contract costs between approximately Rs. 100 and Rs. 300 (approximately US $2-$7) depending on whether it is linked to only a single phase of the monsoon, or all three phases.

In addition, households who buy insurance generally purchase only 1-2 policies, hedging only a modest fraction of monsoon agricultural income, suggesting early adopters are still “experimenting” with the product. Although more recent sales data is not presented in the table, our understanding from BASIX and other sources is that these broad trends have continued in more recent years; the availability of rainfall insurance continues to become more widespread, but the product has not yet gained widespread popularity in the villages where it is offered.

3.1. Barriers to higher insurance takeup

What barriers prevent higher household participation in rainfall insurance markets? Several inter-related possibilities are apparent:

1. **No need for insurance.** Households may not need formal insurance, because of other informal insurance arrangements, the availability of government and bank assistance during times of drought, and so on. Although it seems likely that households are still exposed to rainfall even
after accounting for the effects of this assistance, more research is certainly needed on the effects of drought on consumption and health.

2. **Poor product.** Households may be exposed to rainfall, but have no demand for the available product designed by ICICI Lombard, either because the contract is too expensive, or is poorly designed, or because the household misestimates or ignores its exposure to rainfall shocks.

3. **Households do not understand product.** Most rural households have relatively limited education, and may simply not understand the main features of the product, or be able to accurately estimate the probability of payoffs.

4. **Financial constraints.** Households may have demand for the insurance, but face liquidity constraints. That is, the household may simply not have sufficient liquid assets at the start of the monsoon to purchase it, given competing uses for those funds, such as investment in fertilizer or other agricultural inputs.

5. **Households do not trust the insurance provider.** The household may not trust the insurance to pay out as promised.

In Giné, Townsend and Vickery (2008) and Cole et al., (2009), we study the determinants of household decisions whether or not to purchase ICICI Lombard rainfall insurance, to attempt to disentangle these different explanations.

As a first simple type of evidence, we conduct a set of household surveys across 37 study villages, asking households to describe in open-ended fashion why they did or did not purchase insurance. These responses are classified into one of a number of categories. Households who purchase insurance generally cite reasons relating to “security” or “risk reduction”. Reasons cited by households who do not purchase insurance are presented in Table 2.

<table>
<thead>
<tr>
<th>Table 2: Reasons for non-purchase of insurance</th>
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<tbody>
<tr>
<td></td>
</tr>
<tr>
<td><strong>2004</strong></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
</tr>
<tr>
<td>Insufficient funds to buy insurance</td>
</tr>
<tr>
<td>It is not good value (low payout / high premiums)</td>
</tr>
<tr>
<td>Do not trust insurance provider</td>
</tr>
<tr>
<td>It does not pay out when I suffer a loss</td>
</tr>
<tr>
<td>Do not understand insurance</td>
</tr>
<tr>
<td>Do not need insurance</td>
</tr>
<tr>
<td>No castor, groundnut</td>
</tr>
<tr>
<td>Other</td>
</tr>
</tbody>
</table>
Reasons cited by non-purchasing households evolve somewhat between 2004 and 2006. In 2004, only one year after ICICI Lombard rainfall insurance was introduced, and for most households the first time rainfall insurance had been offered in their village, a significant fraction, 21%, cite “do not understand insurance” as the primary reason why they did not purchase any policies. This fraction falls to only 2% by 2006, as households become more familiar with the product. In 2006, by far the most popular reason cited by households is “insufficient funds to purchase insurance”, suggesting that liquidity constraints are a key barrier to higher participation.

In our research, we also conduct formal regression analysis of the determinants of participation in two regions of India, and implement a set of field experiments where we randomly vary the characteristics of insurance. Interested readers are directed to the two research papers for full details of our research methodology. However, our main findings are as follows:

1. **Liquidity constraints.** Several pieces of evidence suggest that liquidity constraints are an important constraint on participation for many households. First, insurance participation is positively correlated with wealth, even though the benefits of insurance are likely to be stronger for the poorest households. Second, the provision of random liquidity shocks to households significantly increases the probability of purchase. Third, reasons relating to having insufficient liquid funds to purchase insurance are the most common explanation cited by households for non-purchase of the product.

2. **Price.** Insurance participation is sensitive to price. Based on experiments in Gujarat by our co-authors, in which random discounts are offered to households, a 10% decrease in price is estimated to increase product participation by 6.6 - 8.7 percent. This underlines the importance of achieving economies of scale and maximizing competition amongst providers of insurance, so that the insurance can be offered to households at the lowest possible cost.

3. **Trust.** Insurance demand is significantly higher when the product is offered to the household by an agent who is endorsed by someone known to the household.

These findings suggest possible ways to change the product design to stimulate demand amongst consumers. For example, the importance of liquidity constraints suggests policies should be designed to provide payouts as quickly as possible, especially during the monsoon season when our data suggests
households are particularly credit constrained. ICICI Lombard has recently begun installing a network of automatic rain gauges. Amongst other benefits, these gauges will allow them to immediately measure rainfall, calculate policy returns and begin delivering payouts to households. A second possible design change would be to combine the product with a short-term loan, or equivalently, originate loans with interest rates that are explicitly state-contingent based on rainfall outcomes, to help alleviate credit constraints.

4. Hedging

In this section we consider potential risk management concerns facing ICICI Lombard and other underwriters of rainfall insurance. The balance sheet exposure of insurers to rainfall risk is currently limited, given the small amount of rainfall insurance being underwritten. However, these exposures will increase in the future if retail weather insurance gains in popularity.

A key question from an insurer’s perspective is the degree of correlation in payoffs across policies written on different rainfall stations. This degree of correlation will in turn determine the amount of required economic capital to be held against extreme “left-tail” events when average payoffs are high. Some correlation in payoffs is expected, given that insurance payoffs depend on the quality of the monsoon, which is an aggregate event. Furthermore, the fact that the distribution of payoffs on the insurance is highly skewed may exacerbate the risks facing insurance underwriters, since the upper quantiles of losses are extremely large compared to average losses or average premiums (as documented in Figure 2).

In Giné, Townsend and Vickery (2007), we estimate the degree of cross-sectional dependence in payoffs within the state of Andhra Pradesh. We first calculate the standard deviation of phase payouts for each weather station, restricting analysis to the 11 contracts for which we have the most historical rainfall data, using the same rainfall data as described in Section 3.1. The average of these 11 estimated contract standard deviations is Rs. 112.3. We then calculate the standard deviation of the mean insurance payout averaged across the 11 stations at each point in time. The difference between these two statistics reflects the diversification benefits from pooling a portfolio of contracts whose returns are not perfectly correlated. If insurance payouts are independent, the standard deviation of the mean payout will asymptotically be $\frac{1}{\sqrt{11}}$ times as large as the standard deviation of individual contract payouts (i.e. $\frac{1}{\sqrt{11}} \times 112.3 = $Rs. 33.9, a reduction in the standard deviation of payouts of 70%). If payouts are perfectly correlated across contracts, there would be no difference between the standard deviation of the mean payout and those of the individual contracts.

Empirically, we find that the standard deviation of the mean payout is Rs. 60.7, 46% smaller than the average standard deviation of individual contract payouts. This reduction in standard deviation is
smaller than 70%, indicating that insurance payoffs are positively correlated cross-sectionally. However, it indicates that there are surprisingly large diversification benefits from an insurer who holds a portfolio of insurance contracts, rather than an equally sized portfolio consisting only of single individual contract type, despite the fact that all insurance payouts are all based on rainfall in different parts of a single Indian state, Andhra Pradesh. The degree of portfolio diversification would larger if contracts were pooled over a wider geographic area.

An alternative approach to estimating an insurer’s exposure to rainfall risk is to compute extreme quantiles of portfolio exposures, such as the 95th or 99th percentile of losses. Over our sample period, the 99th percentile of the distribution of mean insurance payouts is Rs. 412. This is 13.6 times larger than the mean insurance indemnity, and 4.1 times larger than the mean insurance premium. In contrast, the 95th percentile of mean insurance payouts is Rs. 130, while the 75th percentile is only Rs. 30. These results indicate that the distribution of mean insurance payouts, averaged across 11 weather stations, is highly skewed, similar to the distribution of individual payouts. Extreme rainfall events produce losses that significantly exceed insurance premia collected, at least amongst the portfolio of contracts considered here.

As a final exercise, Giné, Townsend and Vickery (2007) estimates correlations between insurance indemnity payments and several Indian macroeconomic variables, including GDP growth, inflation and stock returns. Such correlations could plausibly be non-zero, because rainfall shocks are likely to be spatially correlated across regions, and the agricultural sector represents a significant fraction of Indian output and employment. Therefore, extreme rainfall events may represent a non-trivial productivity shock for the overall Indian economy.

Again, we calculate putative insurance payouts, assuming that rainfall insurance contracts from 2006 had been available in previous years. Based on a 30 year span of data, we find that mean rainfall insurance payouts are statistically significantly negatively correlated with growth in Indian GDP per capita. Economically, a 1 percentage point decline in GDP growth is associated with an increase in payouts of Rs. 4-5 (i.e., around 15 percent of average contract payouts). This finding suggests that measured rainfall and payouts, beyond being spatially correlated within Andhra Pradesh, are also correlated with aggregate Indian economic activity. One implication of this finding is that remittances from urban workers to family members in drought-stricken areas may be somewhat constrained as a means of sharing risk, since transfers within risk-sharing groups cannot smooth shocks that are aggregate to the group as a whole (Townsend, 1994). Put differently, writing rainfall insurance is a poor hedge, because it produces low returns during periods of low growth, when the insurer is likely to be most financially constrained.
Summarizing this analysis, our evidence suggests that there is a significant systematic component to rainfall insurance payouts, and also that high insurance payouts are correlated with poor macroeconomic outcomes, due to the dependence of the Indian economy on agriculture and the monsoon. These properties of insurance contracts are problematic to an insurer from a risk management perspective. If rainfall insurance was to be written in significant scale, underwriters could limit their risk exposure by selling part of their rainfall risk to a reinsurer, or to hold a significant precautionary capital buffer against potential losses. Past academic literature suggests that both these options are likely to be costly, because of transaction costs, informational frictions and tax concerns (Zanjani 2002; Froot 1999; Froot and Stein 1998). These costs would then be passed on to consumers in the form of higher insurance premia. We note that ICICI Lombard does in fact already use re-insurers to hedge its exposure to rainfall risk, despite the limited amount of coverage it writes, a decision that must be motivated by the existence of some kind of frictions in raising external capital.

6. Conclusions and prospects for retail weather insurance markets
Risk pooling and diversification is a key function of financial markets and the financial system. The product described in this Chapter is designed to diversify the exposure of rural Indian households to a key idiosyncratic risk, variability in local monsoon rainfall. Despite the promise of this type of product, formal rainfall index insurance markets are still in their infancy. The amount of insurance written remains small, and insurance providers are experimenting with different contract designs to better meet consumer needs.

Our field research and household surveys highlight a number of important barriers to household participation in rainfall insurance products, and suggest some tentative lessons for improving product design. For example, we find that household purchase rates are very price-elastic, suggesting that minimizing transaction and administrative costs, and fostering competition, is important to increasing insurance penetration rates. And the observed importance of liquidity constraints highlights the importance of providing payouts as rapidly as possible.

Households in our study areas, unsurprisingly, display limited financial literacy, as measured by their answers to straightforward questions about the time value of money and other financial concepts. This presents an ongoing challenge to the appropriate provision of all types of financial services in the developing world, and also raises the prospect of potentially welfare-reducing predatory selling practices by insurance agents. One potential solution to mitigate these concerns would be for insurance to be purchased by organized groups such as bore well users associations, self-help groups, cooperatives or even a centralized government agent at the local or state government level, rather than by individuals;
funds could then be distributed to households in case of a payout. Another solution would be to combine index-based insurance with a small indemnity based insurance to minimize basis risk.

To summarize, retail weather insurance markets present enormous promise, but these markets are also still relatively immature, and grappling with a variety of design and implementation challenges. Amongst other factors, improvements in technology should help to further promote prospects for weather insurance markets in future years. For example, technology can help improve the availability of historical data and modeling tools for accurately calculating expected payouts and pricing policies, and satellite images could in principle be used to quickly and directly measure crop yields in a localized geographic area, and insurance based on those yields rather than rainfall, reducing basis risk.

7. References and further reading

A. Primary sources


B. Other cited references


