Innovative Insurance Design: Enhancing the Role of Private Firms in Strengthening Rice Cultivation's Resilience to Climate Change in Bangladesh

Authors: Robert M. Townsend, Kamilya Tazhibayeva

We develop a structural and computational framework that improves compensation accuracy of weather-indexed crop insurance through individualised coverage. Our design remains purely weather-contingent and thus retains the main advantages of standard, non-customisable weather-indexed insurance.

Introduction

Climate change threatens the food security and income source of Bangladesh's most vulnerable population, smallholder farmers. Bangladesh's dominant crop and main staple is rice. Rice yields can be substantially reduced by both high and low rain and temperature. Even the mildest climate change will significantly exacerbate the incidence and magnitude of weather fluctuations [1], putting both rainfed and irrigated rice cultivation in Bangladesh under severe strain. No existing rice variety can withstand extreme temperature stress, which is already possible in Bangladesh. Ground water, which is the main source of irrigation, is already being depleted and under increasing stress, particularly during drought years. At the same time, rapid population growth and the acceleration of urbanisation, which competes with crop cultivation for land and water use, call for urgent increases in rice yield [2].

The existing crop insurance products either do not properly reimburse farmers for weather-related losses or are prohibitively expensive. Without viable risk-sharing tools, farmers opt for low-cost, low-yield cultivation practices, such as conservative timing of planting, and broadcasting of seeds rather than transplanting of seedlings (the latter is substantially more labour-intensive and costlier) [2] [3] [4] [5] [6] [7] [8]. The choice of planting method alone can lead to a five- to six-fold change in potential yield [9] [10]. This means that when the weather is favourable, crop output is much lower than potential yield.

Our goal is to improve the low coverage accuracy of weather-indexed (WI) crop insurance. As its name suggests, WI insurance pays out only conditional on the occurrence of easily observable weather events that farmers cannot influence. This is a straightforward and inexpensive process, making WI products low-cost and uncomplicated to provide. One major source of its low coverage accuracy is the variation in effect that the same local weather event can have on crops grown on different plots and with different timing of cultivation activities. We address this source of coverage inaccuracy by directly incorporating such individual variation into the structural and computational models we then use to design insurance coverage.

In the literature on development economics there is a consensus on the main reason for the low uptake of WI insurance by farmers: these are the prevalent discrepancies between covered and sustained losses [4] [11] [12] [13] [14] [15] [16]. Evidence from previous field experiments has shown that when farmers take up WI insurance, they invest more in their crops, including in timely execution of key cultivation activities. This, in turn, improves yields and strengthens food security and climate change resilience [4] [17] [15] [18] [16] [14] [19] [20] [21].

Methodology

By construction, WI insurance treats local weather effects on crops as aggregate, when in reality these effects can vary across plots and farmers. As a result, existing WI designs completely decouple weather from any individual (farmer or plot) characteristic, generating structural discrepancy in individual coverage. One major source of this heterogeneity is the timing of cultivation activities, because crop's requirements for, and vulnerability to, moisture and temperature vary during its growth. Because crop growth is sequential, this direct heterogeneous effect, by affecting crop's current health, introduces additional variation into the effects of upcoming weather on the crop during the rest of the growth cycle.

Our work resolves this structural discrepancy by accurately capturing the heterogeneous effects of weather on yields. To achieve this, we specify a nonlinear, nested multistage model of rice cultivation, with stages corresponding to main crop growth phases. Timing in our model is explicitly based on crop growth phases, incorporating individual variation. Cultivation stages are sequential, thus they directly incorporate the temporal effect of earlier weather shocks and input use on crop's responsiveness in later growth phases.

We use this structural framework in combination with a meteorological weather model and survey data to simulate a comprehensive dataset of weather histories and rice cultivation outcomes. For any potential history of daily weather, this dataset contains all possible realisations of input use and yields, reflecting variations in cultivation outcomes due to differences in the timing of cultivation activities.

Main Findings

This explicit differentiation enables us to specify customised weather-contingent coverage for individual farmers and plots. This provides farmers with more accurate coverage against adverse weather shocks. Being contingent only on realised weather, our proposed design retains the desirable features of existing WI products: low cost, ease of implementation, and inability of farmers to influence their payoffs by subsequent actions.

Our framework can accommodate differences in farmers' preferences towards the severity of risk they seek coverage for, from mild to extreme. This addresses another gap in provision of risk-sharing products, as coverage for milder but more common shocks is valued by farmers but generally not available. We also adapt our insurance framework to alternative climate change scenarios predicted by the Intergovernmental Panel on Climate Change (IPCC).

Our theoretical results expose the impacts that differences in timing of cultivation activities across plots, and the lengthy and sequential nature of crop growth, have on farmer's behaviour, variation in yields across plots in similar environments, and deviation of actual yields from potential.

Sequential feedback makes it easy for small discrepancies in timing at the start of the growth cycle to snowball over the cultivation cycle into substantial deviations from optimal yield and into large variation in yields across plots, giving rise to significant variation in required coverage. Our results underscore the substantial practical impact of providing farmers with easy access to accurate and timely local weather data and forecasts.

Policy Impact

The flexibility of our proposed design will enable firms to provide insurance to small and marginalised farmers, many of whom often get inadequate coverage from existing WI products, and many of whom are women. Its improved accuracy and affordability will increase farmers' ability to adapt to and withstand the adverse effects of weather shocks and climate change on their crops. Our work also informs discussion on the role of private firms in promoting weather and climate change resilience and adaptation via risk sharing in LICs.

Our framework enables the categorisation of potential weather scenarios, conditional on already observed weather being "good" (high yield) or "bad", and the computation of their conditional probabilities. In our current work, we do this at the farmer or farmer-plot level. Our framework also allows performing this analysis at a village or a more aggregate level. This can provide early warnings of looming weather calamities to local authorities, farmers, and markets. Such early warnings can improve preparedness and facilitate timely relief interventions in the case of sufficiently strong adverse weather impacts on yields.

Next Steps

Going forward, we plan to expand our framework to promote positive environmental change in cultivation practices among farmers in developing countries, with the goal of diminishing farmers' vulnerability to weather and climate shocks. We will use our approach to evaluate the effect of underdeveloped insurance markets and perceived high costs of trying new practices on yields and climate change resilience.

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