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Flexible weather index-based insurance design

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ABSTRACT

This study investigates the performance of a flexible index design for weather index-based insurances using farm-level panel data on wheat production from Kazakhstan. The proposed flexible design is a generic framework that uses Growing Degree Days to determine annual variable start and end dates for the insured period. This approach reflects the progress of phenological plant growth phases more accurately than fixed periods and hence is expected to reduce the basis risk of the index insurance. In addition, we develop an economic framework that focuses on the role of downside risks and apply Quantile Regression to tailor optimal insurance specifications. This framework is then used to compare the downside risks associated with the use of flexible and fixed insurance periods. The results show that the introduction of flexibility in the index design leads to a reduction in farmers' downside risk exposure and to a more efficient contract design.

Introduction

Agriculture production depends heavily on weather conditions. While idiosyncratic adverse weather impacts can be managed through informal measures, systemic weather events require formal risk management approaches such as insurances. Traditional indemnity based insurances however, are plagued by asymmetric information problems[1] and high transaction costs (Chambers, 1989). Index-based insurance products overcome these challenges by conditioning the payout not on actual yield losses but on the realization of an independent and transparent index. For weather index-based insurances, the index is designed to adequately reflect weather conditions, which decisively influence crop yields or better crop yield reductions in a specific region[2]. However, the discrepancy between index and crop yield loss leads to a residual risk borne by the insured farmer that is referred to as basis risk (Woodard and Garcia, 2008).

Along these lines, it has been shown that the basis risk decreases with a higher correlation between the chosen weather index and crop yield, which implies a higher effectiveness and higher potential up-take of these risk transfer products (Fuchs and Wolff, 2011). Improving the index insurance design is therefore a key challenge to achieve the potential benefits from weather index based insurances (Fuchs and Wolff, 2011; Woodard and Garcia, 2008; Norton et al., 2013). Most studies use a simple index based either on rainfall or temperature, summing up the weather information within the main vegetation period of a specific crop in a specific region (cf. Turvey, 2001; Martin et al., 2001; Barnett and Mahul, 2007; Berg and Schmitz, 2008; Kellner and Musshoff, 2011; Daron and Stainforth, 2014). However, these studies rely on indices that are based on

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[1] The main challenges of asymmetric information problems are moral hazard and adverse selection. Both may lead to insurance market failure.
[2] Note that alternative approaches focus on the use of other index sources such as remote sensing data (see e.g. Hochrainer-Stigler et al., 2014, for details).

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fixed calendar dates. This means that each year the weather information is calculated in the exact same period, i.e. the yearly start and end days are identical (e.g. often chosen are start and end dates of months).

The fixed calendar date approach, however, neglects important information. First, it does not consider that the vulnerability of a specific crop changes across phenological phases (Nairizi and Rydzewski, 1977). Second these critical phases are in actual crop growth not constant with regard to calendar times but depend on external weather conditions. It has been acknowledged in previous research that the interaction between damaging weather event and the specific plant growth stage is important and that this information has to be incorporated in the index design (cf. Nieto et al., 2010). More specifically, Nieto et al. (2010) describe a procedure that divides the growing period into 10 days intervals and weights these decades by the sensitivity of the crop yield towards the index. Even though this approach integrates the plant sensitivity during different phenological phases, the specification of the considered decades is fix over the years, i.e. start and end dates remain unchanged.

The explicit consideration of plant growth stages in the index-based insurance literature is rare. For instance, Leblois et al. (2013) use observed and modeled sowing information to incorporate the timing of biological processes in an insurance application. Kapphan et al. (2012) extract information on phenological plant phases from a crop model and use Growing Degree Days[3] (GDD's) for index construction, however applying only simulated data. Not focusing on insurance applications, Meyer et al. (1993) developed a drought index for corn by relying on GDD's to detect the progress of plant growth throughout the growing season. Their results show that using GDD's indeed could contribute to a better explanation of the vulnerability of plant growth to drought events. Thus, a generic approach to describe crop growth stages flexibly across years based on GDDs tends to be superior to an approach using fixed dates to specify potentially critical phases.

Based on this background, we expect a stronger dependency between the weather index and the actual crop yield by using flexible time periods (defined through GDD's) instead of fixed calendar dates to specify the index. Considering this element in the design of an index could result in transparent insurance solutions that reduce the basis risk and thus potentially improve the effectiveness and uptake of index-based insurance solutions. This link has, however, not been addressed in the literature so far.

The here presented study extends previous research in several directions. First, we develop a GDD concept to determine annual start and end dates of a cumulative index. Second, we compare and quantify potential benefits of this approach to the standard approach where fixed calendar dates are used to specify the index accumulation period. Third, we establish a consistent downside risk perspective, which aims to reduce the probability of exceeding certain loss thresholds from index design to risk evaluation of the index-based insurance contract. Our empirical application focuses on wheat farms in northern Kazakhstan.

The remainder of the article is structured as follows: In Section "Methodology and empirical procedure", we present our methodology. More precisely, this section introduces the index insurance framework, the expected utility approach to evaluate our results and the procedure how to derive two indices: a flexible with varying yearly calendar dates and a fixed index with constant yearly dates. This section also introduces the case study on wheat production in Kazakhstan and presents the data. The results are shown in Section "Results", followed by the discussion of the results and the conclusion in Section "Discussion and conclusion".

Methodology and empirical procedure

In a first subsection, we explain the index insurance framework applied in our analysis and derive an expected utility approach based on mean and semi-variance. We adapt this approach to our objective function in the second subsection. In the third subsection, we describe the GDD concept and the index design approach. In the fourth subsection, we present our case study and explain the empirical procedure.

Conceptual framework

Index-insurance framework

Consider a farmer who is confronted with production risks due to varying weather conditions. Crop yield y is expressed as a function of weather, represented by a weather index WI. Additional factors that affect crop yields but are uncorrelated with WI, are summarized within the term ε.

$$y = g(WI) + \varepsilon \tag{1}$$

We assume that farmers are risk averse and purchase a weather index insurance to reduce their risk exposure. Following Deng et al. (2007), the farmer is assumed to hold only two assets: the production of one single crop and the index insurance contract, which is a valid assumption as our sample consists of Kazakh farmers solely focusing their production on wheat. In addition, wheat grown in northern Kazakhstan is characterized by low-cost, low-input and rain-fed agriculture, which justifies the simplifying assumption that production inputs are independent of weather realizations (cf. also Turvey, 2001).

[3] GDD is a measure of heat accumulation and reflects the importance of temperature as a crucial driver of plant growth (McMaster and Wilhelm, 1997).