Extended Abstract

Paper Title	**The hedging effectiveness of satellite-retrieved vegetation indices – The case of northern and eastern Germany**

Abstract prepared for presentation at the 98th Annual Conference of The Agricultural Economics Society will be held at The University of Edinburgh, UK, 18th - 20th March 2024.

Abstract	***200 words max***
Index insurance is a promising tool to mitigate drought-related income losses in agriculture. Yet, the basis risk of index insurance based on meteorological observations inhibits farmers' demand in Europe. To increase the hedging effectiveness (HE) of index insurance, the integration of satellite-retrieved vegetation indices has received research attention. However, given limited knowledge regarding their HE in a European context, we use winter wheat yield data from 79 farms in Germany to investigate the potential of index insurance based on satellite-retrieved vegetation indices. We designed index insurance based on three satellite indices: The Vegetation Condition Index (VCI), the Temperature Condition Index (TCI) and the Vegetation Health Index (VHI) with a spatial resolution of 1x1km. As the benchmark, a meteorological index related to precipitation is employed. The results indicate that, on average, the TCI and VHI outperform the benchmark index in a statistically significant way. However, considerable differences among regions are observed. Particularly, the highest HE was found for farmers in Brandenburg and Saxony Anhalt. The results are of interest to insurers who are developing new insurance products and to policymakers who are considering policy intervention. Moreover, researchers focusing on designing index insurance can benefit from this study.	

Keywords	Risk management, Index insurance, Satellite data, Hedging effectiveness
JEL Code	Q12

Introduction	***100 – 250 words***
In Central Europe, catastrophic droughts caused by climate change occur more frequently and affect crop yields negatively (Grillakis, 2019). In Germany, drought has already been the most economically relevant production risk for crops (Schmitt et al., 2022). To cope with drought-related yield losses, index insurance is discussed because it can mitigate liquidity constraints. Furthermore, drawbacks of traditional indemnity-based insurance such as adverse selection or moral hazard can be addressed. However, the demand of index insurance remains low given basis risk concerns. To address several sources of basis risk, researchers have turned their attention to satellite data. While the HE of satellite-retrieved soil moisture has received sufficient research intention (Vroege et al., 2021), Möllmann et al. 2019 is the only study that investigated the HE of satellite-retrieved vegetation indices for insurance purposes in a European context. Although the authors provide initial insights	

suggesting that vegetation indices can enhance HE, their sample size and regional focus are limited, offering insufficient guidance for insurers and policymakers in designing index insurance. Therefore, we contribute to the existing literature by investigating the HE of satellite-retrieved vegetation indices with a high spatial resolution, using yield data from a large sample in Germany. This is of high relevance as the share of German farmers who have index insurance still remains at 1-2% which is unique for such a developed country (Nordmeyer and Mußhoff, 2023). Furthermore, recent research has shown that farmers prefer satellite-based index insurance over precipitation-based (Nordmeyer et al., 2023).

Methodology	***100 – 250 words***

In order to investigate the HE, we use winter wheat yield data between 2000 and 2019 from 79 farms located in northern and eastern Germany. We developed four index insurance products for each farm. The coverage period of the index insurance was defined by the critical phenological growth stages between stem elongation and beginning of milk ripeness in any case (Dalhaus et al., 2018). With respect to the satellite indices, we use public available MODerate-resolution Imaging Spectroradiometer (MODIS) satellite data to calculate the VCI, TCI and VHI. These indices were calculated at a spatial resolution of 1x1 km, with a temporal resolution of 16 days for the VCI and 8 days for the TCI. For each farm, we considered the mean value of a minimum of 5 satellite images within a 5-10 km circle around the farm. The benchmark index was designed as the average sum of precipitation from three weather stations around the farm, provided by the German Meteorological Service. The strike level and tick size were determined by applying Quantile regression (Conradt et. al, 2015). For the pricing of the index insurance, a burn-rate analysis was employed. To measure the HE, we considered the expected shortfall. The HE was, thus, defined as the change of the expected shortfall of the winter wheat revenue by the use of an insurance contract. Finally, Wilcoxon rank tests were applied to detect statistically significant differences in HE.

Results	***100 – 250 words***

Following Conradt et al. (2015), we focus on the 0.3 quantile of the winter wheat revenue distribution. Based on the burn-rate analysis, the HE was calculated under a fair premium scenario. The Wilcoxon rank test reveals that, on average, the TCI and the VHI statistically significantly outperform the benchmark precipitation index. In particular, the VCI leads to higher HE of 2.1% on average, the VHI to a higher HE of 2.0%. No statistically significant difference in HE was found for the VCI (1.4%) compared to the precipitation index (1.4%) on average. Most interestingly, we detect statistically significant differences between the federal states. Particularly, the highest HE on average for the TCI (4.7%) and VHI (4.1%) was observed for farmers in Brandenburg on average. Furthermore, the highest HE for the VCI (5.5%) was observed for farmers in Saxony Anhalt. On the contrary, no statistically significant increase in the HE was found for farmers in Lower Saxony on average. In Saxony and Thuringia, the TCI and VHI outperform the benchmark, however, the average HE in these federal states is lower compared Brandenburg, for example. Our results remain robust when extending the coverage period by considering observations before and

after the defined coverage period. Furthermore, the findings hold true when focusing on the 0.4 quantile of the winter wheat revenue distribution.

Discussion and Conclusion	***100 – 250 words***

Our results show that index insurance based on the TCI or VHI can increase the HE compared to precipitation on average. More specifically, their potential is statistically significantly higher in regions with sandy soils like Brandenburg and Saxony Anhalt which are therefore more prone to droughts. Hence, insurers can be advised to accelerate research and development of satellite-based index insurance in these regions. By considering our insurance design, products with low transaction costs and therefore comparatively low loading factors can be offered to farmers in these regions. In contrast, farmers in Lower Saxony still lack sufficient insurance schemes as no statistically significant increase in the HE was found on average even though they also experienced high drought-related yield losses. Thus, ongoing research in needed to identify drought indicators on better soils. Policymakers can be advised that index insurance products using satellite data can improve the risk management of many farmers in eastern Germany. However, it's important to note that, in relative terms, the HE of the index insurance products in our case study is lower compared to studies focusing on individually-tailored index insurance. This highlights the trade-off between individually-tailored index insurance and index insurance with low transaction costs. Furthermore, it can be argued that the focus on county level instead of farm level could improve the HE as this was shown by Möllmann et al. 2019. Nonetheless, one should keep in mind that increasing the complexity of index insurance products reduces market acceptance (Odening and Shen, 2014).

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