ETH zürich

Reducing basis risk of weather index-based insurance by evaluating a set of promising drought indices

Janic Bucheli

Agricultural Economics and Policy Group

ETH Zurich

AECP
Agricultural Economics and Policy

Drought Risk in Plant Production

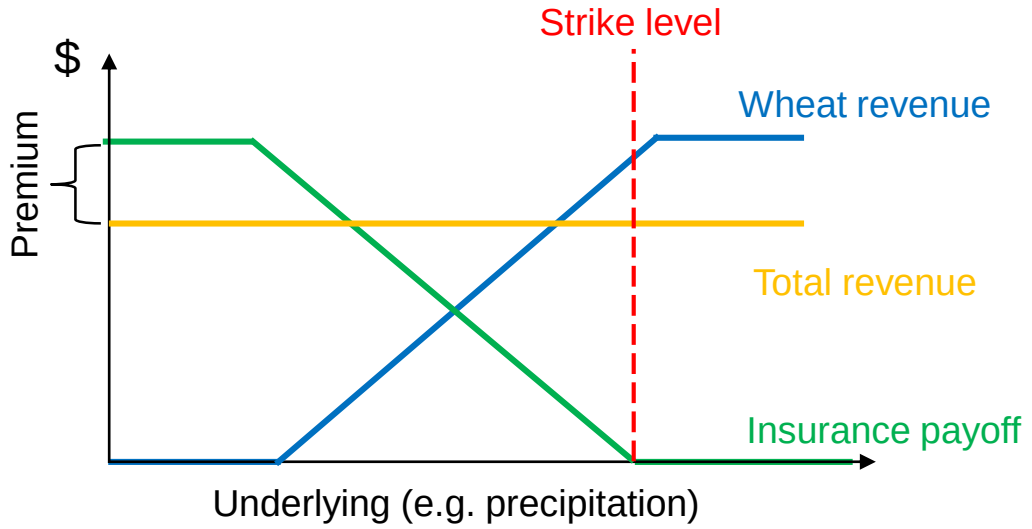
- Drought is a major contributor to financial downside risks
  - Climate change increases drought risks in most regions[1]
  - Recent droughts in Central Europe: 2003, 2015, 2018
- Drought risk management becomes more important
  - Agronomic measures (e.g. irrigation) costly and sometimes unreliable
  - Limited insurability with traditional insurance solutions
    - Systemic nature of drought
    - Asymmetric information problems

Lobell, David B., Wolfram Schlenker, and Justin Costa-Roberts. "Climate trends and global crop production since 1980." *Science* 333.6042 (2011): 616-620. [1]

Weather Index-based Insurance (WII)

- Alternative drought insurance solution[2]
  - Indemnification is not loss- but risk-based
  - Underlying drought index determines payout
    - Overcomes asymmetric information problems
    - Reduces problem of systemic nature of drought
  - Basis risk
    - Discrepancy between payout and experienced loss
    - Identify underlying with most accurate yield prediction

Stylized illustration of WII



Vedenov, Dmitry V., and Barry J. Barnett. "Efficiency of weather derivatives as primary crop insurance instruments." *Journal of Agricultural and Resource Economics* (2004): 387-403. [2]

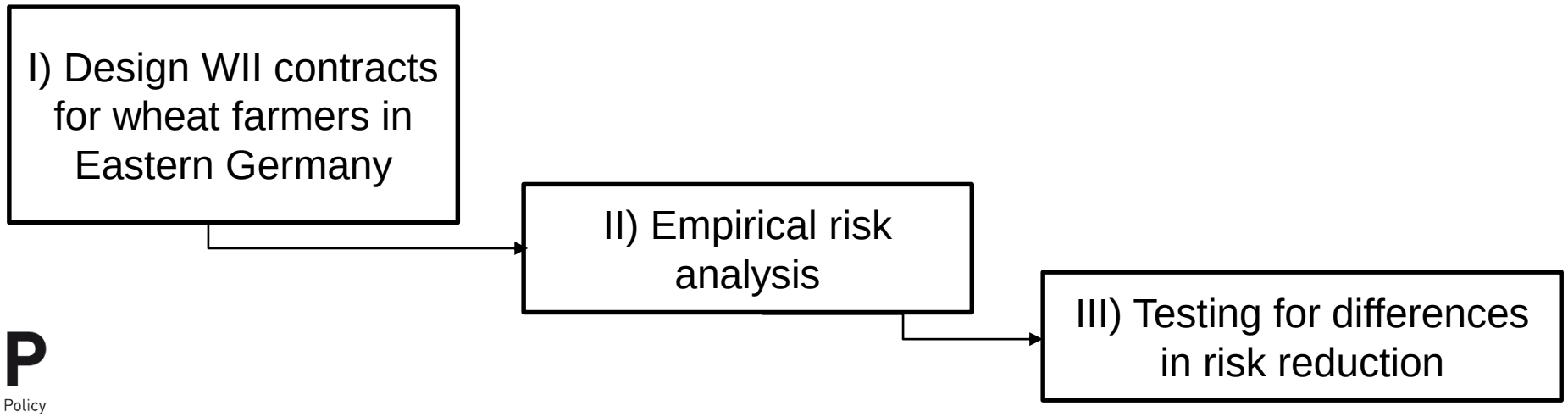
Research question and setup

Which is the most appropriate drought index to reduce basis risk?

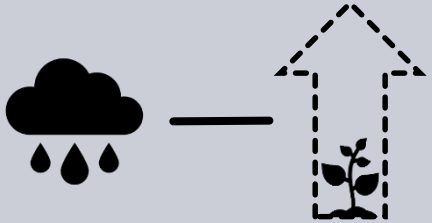
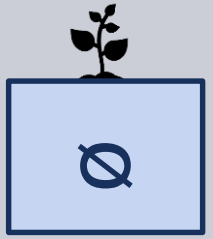
We test five prominent drought indices forming an information gradient

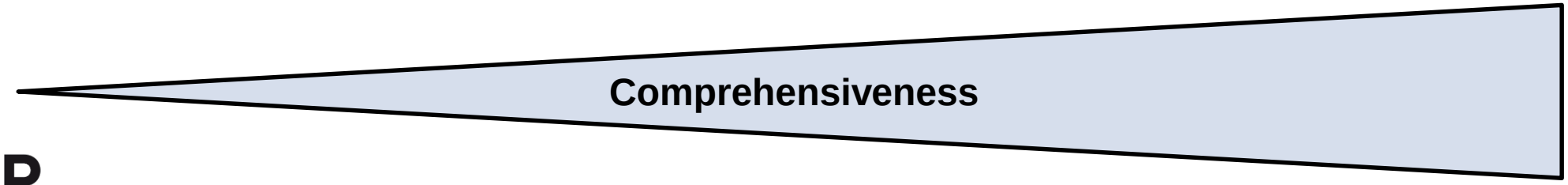
i) Regarding their ability to serve as underlying in WII

ii) Whether there is the optimal drought index for all farms or whether farm-specific tailoring of the WII underlying could be more viable



An information gradient of 5 prominent drought indexes

Cumulative precipitation index (CPI)	Standardized precipitation index (SPI)	Standardized precipitation evapotranspiration index (SPEI)	Soil moisture index (SMI)	Evaporative stress index (ESI)
				
Sum of precipitation	Standardized anomalies in the cumulative precipitation index	Standardized anomalies in the difference between precipitation and potential evapotranspiration	Average plant available field capacity	Standardized anomalies in the ratio of actual to potential evapotranspiration

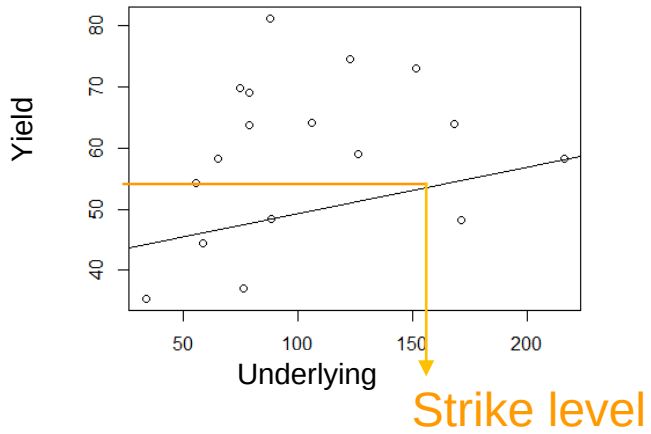


Step I) Design of individual WII contracts for winter wheat

- Flexible period of index measurement that reflects most critical growth phases of stem elongation to the beginning of milk ripeness[3]

- Payout formula follows structure of a European put option
  - Quantile regression tailors payout to farm-specific index-yield relationship[4]

$$Payout = Price * Tick\ size * max\{(Strike\ level - Index), 0\}$$



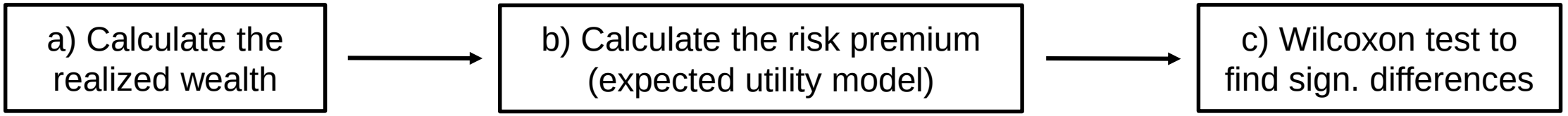
- Tick size: Yield reduction per missing unit of underlying drought index
  - Equal to slope coefficient of quantile regression

- Strike level: Undercutting this value triggers a payout
  - Equal to the inverse of quantile regression for average yield

Dalhaus, Tobias, Oliver Musshoff, and Robert Finger. "Phenology information contributes to reduce temporal basis risk in agricultural weather index insurance." *Scientific reports* 8.1 (2018): 46. [3]

Conradt, Sarah, Robert Finger, and Raushan Bokusheva. "Tailored to the extremes: Quantile regression for index-based insurance contract design." *Agricultural economics* 46.4 (2015): 537-547. [4]

Step II & III) Empirical risk analysis and testing



a) $Realized\ Wealth_{it}^{k} = Price * Yield_{it} + Payout_{it}^{k} - Premium_{i}^{k}$

- Actuarially fair premium & deterministic wheat price of 15.80 Euros per deci-tons

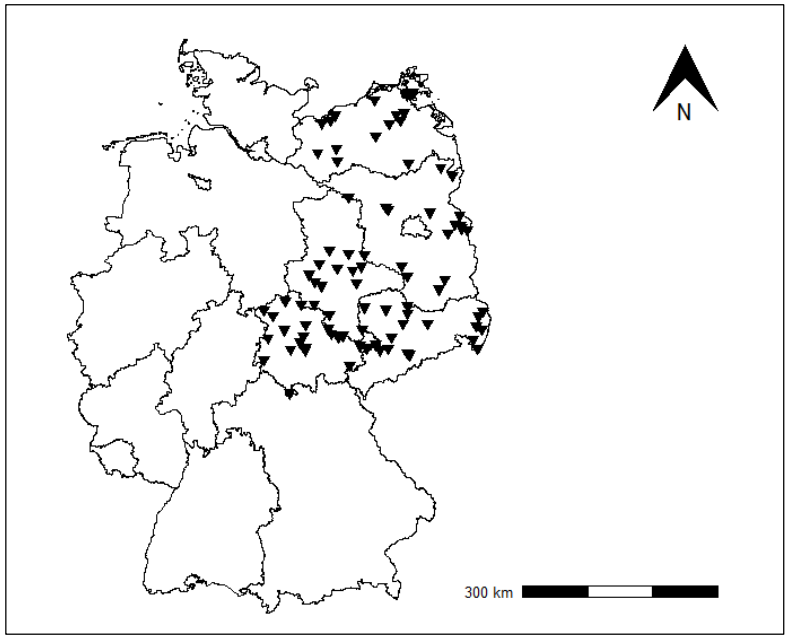
b) Risk premium reflects implicit costs of the risk burden

- The lower the risk premium the lower the risk exposure
- Power utility function under assumption of moderately risk-averse farmers (CRRA = 2)

c) One-sided Wilcoxon signed rank tests with Bonferroni corrected significance level

Case study and data

- Unbalanced panel consisting of 85 winter wheat producers in Eastern Germany (yield data 1995 - 2015)
- Publicly available datasets on phenology and weather records provided by German Meteorological Service
  - Phenology from a network of growth phase reporters
  - Gridded datasets for weather records (daily 1 km x 1km)



Results: Average changes in the risk premium

Average risk premium uninsured: 28.27 Euros per ha

Table 1: Average difference in the risk premium (RP) and its significance.

		RP_n					
	m/n	**CPI**	**SPI**	**SPEI**	**SMI**	**ESI**	**Uninsured**
RP_m	**CPI**	---					**- 3.44*** **
	SPI	**- 0.29***	---				**- 3.74*** **
	SPEI	0.46	0.75	---			**- 2.99*** **
	SMI	0.16	0.45	-0.30	---		**- 3.28*** **
	ESI	**- 2.04****	**- 1.75***	**- 2.50*** **	**-2.20*** **	---	**- 5.49*** **
	BEST	**- 3.73*** **	**- 3.44*** **	**- 4.19*** **	**- 3.89*** **	**- 1.69*** **	**- 7.17*** **

Notes: Numbers display the average reduction in the risk premium (RP_m – RP_n) in Euros per hectare. Asterisks indicate the Bonferroni-adjusted significance level for the result of the Wilcoxon signed rank tests: * at the 1% level, ** at the 0.2% level, *** at the 0.02% level. Significant results highlighted in bold. Null hypothesis of Wilcoxon signed rank tests: $RP_m \geq RP_n$.

- On average, all of the five drought indices have the potential to reduce financial downside risks
  - The removal of drought risks exceeds basis risk
- On average, the evaporative stress index (ESI) has a significantly lower basis risk than the other indices
  - Average risk reduction of 19.42%
- Non-uniform insurance product (BEST) is significantly better than the uniform insurance products
  - Average risk reduction of 25.36%
  - BEST comprises all 5 drought indices!

Discussion

- The applied drought indices have risk-reducing potential
- Yet, there is not “the” best underlying
- Tailoring the underlying to each farm

Discussion

- Why are more comprehensive drought indices not always better?
  - Data quality (method of data collection, interpolation)
    - Precipitation is *measured* at *5'000 stations*
    - Soil moisture and evapotranspiration is *modelled* over grass on sandy loam *at 280 stations*
  - Drought is not a unique natural hazard
    - Variety of drought occurrence and complex manifestations in agricultural systems
    - Drought indices differ in their ability to capture different manifestations

Limitations

- *Ex-post* analysis for winter wheat producers in Eastern Germany using the actuarially fair premium
  - Future climate development might influence optimal index design
  - Validity of our findings for other crop-region combinations
  - Risk-reduction potential depends on insurance markets and their regulation as well as alternative risk management tools

Conclusion & Outlook

- Weather index-based insurance can reduce financial drought risks
- There is not a universally best underlying available yet
  - Hence, there is a need to tailor the underlying to each farm
- Extend the set of drought indices and apply this set on other crops and regions
- Develop WII that covers other risks that are difficult to insure
  - E.g. excessive precipitation, heat waves

ETH zürich

Thank you for your attention

jbucheli@ethz.ch