Actuarial Insights into Climate-Resilient Parametric Insurance for Sustainability

Ezgi Nevruz

Hacettepe University & Actuarial Society of Türkiye

5th European
Congress of Actuaries
www.eca2024.org

About the speaker

- **Ezgi Nevruz –** *Research Assistant, Department of Actuarial Sciences, Hacettepe University*

She is a registered actuary and the academic delegate of the Actuarial Society of Türkiye. She has been also the member of the AAE's two Working Groups called Sustainability and Climate-Related Risks (SCrR) and European Actuarial Climate Index (EurACI). She received her PhD, MSc and BSc in Department of Actuarial Sciences and minor degree in Department of Economics at Hacettepe University. Her current research on sustainability includes climate-related risks, agricultural insurance, stochastic ordering, risk prioritization, risk clustering, and loss of income.

- **Department of Actuarial Sciences** is established in 2000 under the Faculty of Science at Hacettepe University and started its undergraduate education in 2002. Currently, the department offers BSc, MSc and PhD (*unique in Türkiye*) degrees.
- Established in 1951, **Actuarial Society of Türkiye** is currently a full member of the IAA and AAE.

Outline

- **Introduction and Aim**
  - The motivation: “Paragliding” as a case study
  - The concept of climate resilience in terms of risk/uncertainty perception: A survey study

- **Actuarial Insights into Parametric Insurance**
  - Key features of parametric insurance
  - Discussion: Parametric insurance vs traditional indemnity-based insurance
  - Actuaries Climate Index (ACI) as a candidate for “trigger”
  - Challenges and suggestions

- **Sustainability: Future Directions and Conclusions**

Aim of the study

science.nasa.gov

www.wordclouds.com

This study aims to investigate the relationship among climate risk management, risk perception, sustainability, and actuarial science, with a particular emphasis on the concept of **parametric insurance**.

unesdoc.unesco.org

riskandinsurance.com

The motivation: "Paragliding" as a case study

"Once a sport defined by a ***harmonious dance with nature****, paragliding now faces a formidable foe:* ***climate change****. … Unlike other forms of aviation, paragliding offers the purest form of flight–no engines, no fuel, just the pilot and the boundless sky. But it's not speed or height that makes paragliding exhilarating. Instead it's the deep satisfaction that comes from mastering* ***the art of reading the sky*** *and working in harmony with the wind itself. …"*

from the article called "Can Paragliders Adapt to Climate Change? The Future of Flight" by Priya Kavina, *The Momentum.*

The motivation: “Paragliding” as a case study

Which one is riskier? Paragliding or driving?

“When we look at the general statistics, we see that traffic accidents are in the eleventh place with a 2% share in the world's death rankings. The risk in paragliding is seen as 7/100.000. Looking at these statistics, ***driving in traffic carries much, much more risk than paragliding.*** *So you can make your flights safely and peacefully.”* from https://fethiyeyamacparasutu.net/

- **Statistics and perception:**
  - **Exposure** as a component of risk: “The length of driving time” is shown to be an alternative measure to “driving distance” for driving exposure (Shen et al., 2020).
  - Consider **“paraglider-hour”** as an exposure: The fatality rate is 1.6 per 100,000 hours of paragliding (Wilkes et al., 2022) whereas the average fatal crash rate is calculated as 59.9 per 100million hours driven (Shen et al., 2020).
  - This result implies that paragliding is 26 times more fatal (*not 2,857 times less fatal*) than driving.

Photo by Kenan Olgun
Baba Mountain/Ölüdeniz/Türkiye, which is one of the favorite paragliding regions in the world.

The motivation: “Paragliding” as a case study

Paragliding is a dangerous sport, even for senior pilots. Novice pilots with low air-time are the most exposed to **adverse wind and weather conditions** and as a result can suffer serious injuries especially when their **equipment is not of good quality.** Despite this, **limited experience** can lead to **overconfidence** and the desire to “be good” at sports. This is called ***“Icarus Syndrome”*** (Yuill, 1977).

Climate resilience refers to the ability of managing the risks associated with the **climate change**. In addition to quantitative measurements, ***“risk perception”*** is also determined by subjective aspects of risks influenced by many factors including **personal experiences,** cultural beliefs, **and socio-economic conditions** (Nevruz, 2018).

Growing awareness of **how climate resilience influences risk/uncertainty perception** may result in more practical **insurance applications**.

The concept of climate resilience in terms of risk/uncertainty perception: A survey study

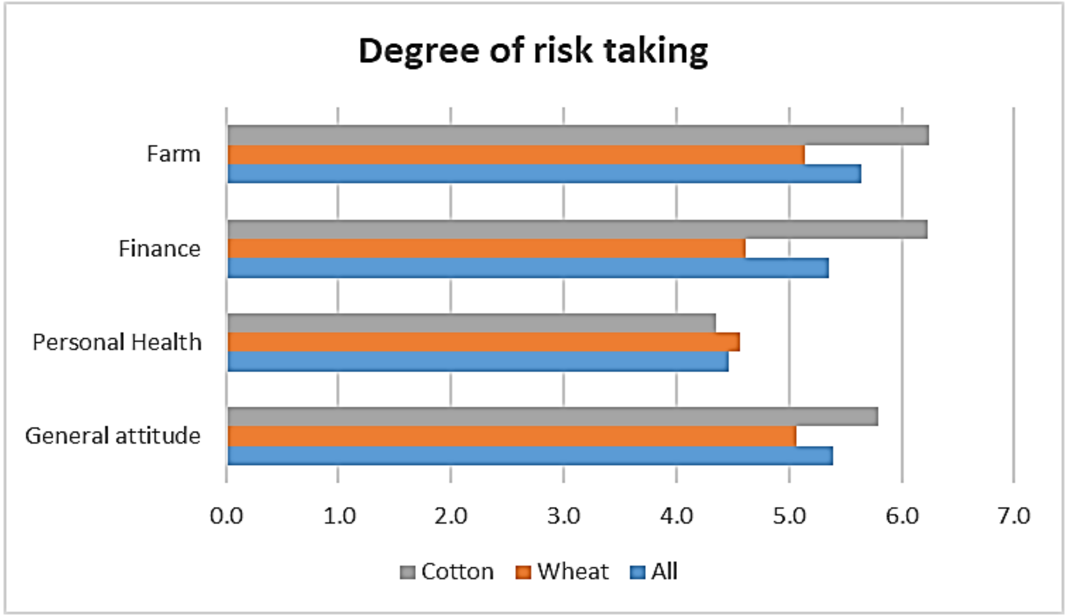
Climate resilience		Risk/Uncertainty perception	
✓ Anticipate ✓ Prepare for ✓ Adapt to	the climate change	✓ Understand ✓ Assess ✓ Respond to	the climate risk

- The objectives of the project called *"Developing Alternatives for Agricultural Risk Management for Small Farmers in Agri-Food Value Chains" (FAO, 2023):*
  - To review and assess the risk environment in Turkish agriculture
  - To conduct a comparative evaluation of the Agricultural Risk Management (ARM) tools
  - To develop a set of recommendations for public policies to help smallholders cope with the risks in agri-food value chain context

- **A risk prioritization analysis** is performed with a **survey study** which enables us to make suggestions for developing alternative ARM tools.

The concept of climate resilience in terms of risk/uncertainty perception: A survey study

- We used survey data collected from **smallholder farmers trading on commodity exchanges**.
- Two strategic **crops**, which are raw material needs of food industries and manufacturing and foreign trade policies, were chosen: wheat and cotton
- The selected **provinces** according to the production level and trading volume of the commodity exchanges : Ankara (Polatlı), Konya, Eskişehir, Edirne, Şanlıurfa, İzmir



According to the results of the quantitative regression analysis, the farmer's risk taking level, which is an indicator of risk perception, is explained by:

i. assets value,
ii. being exposed to losses exceeding 30 percent of total production in the last five years, and
iii. the importance of the farm development among given priorities.

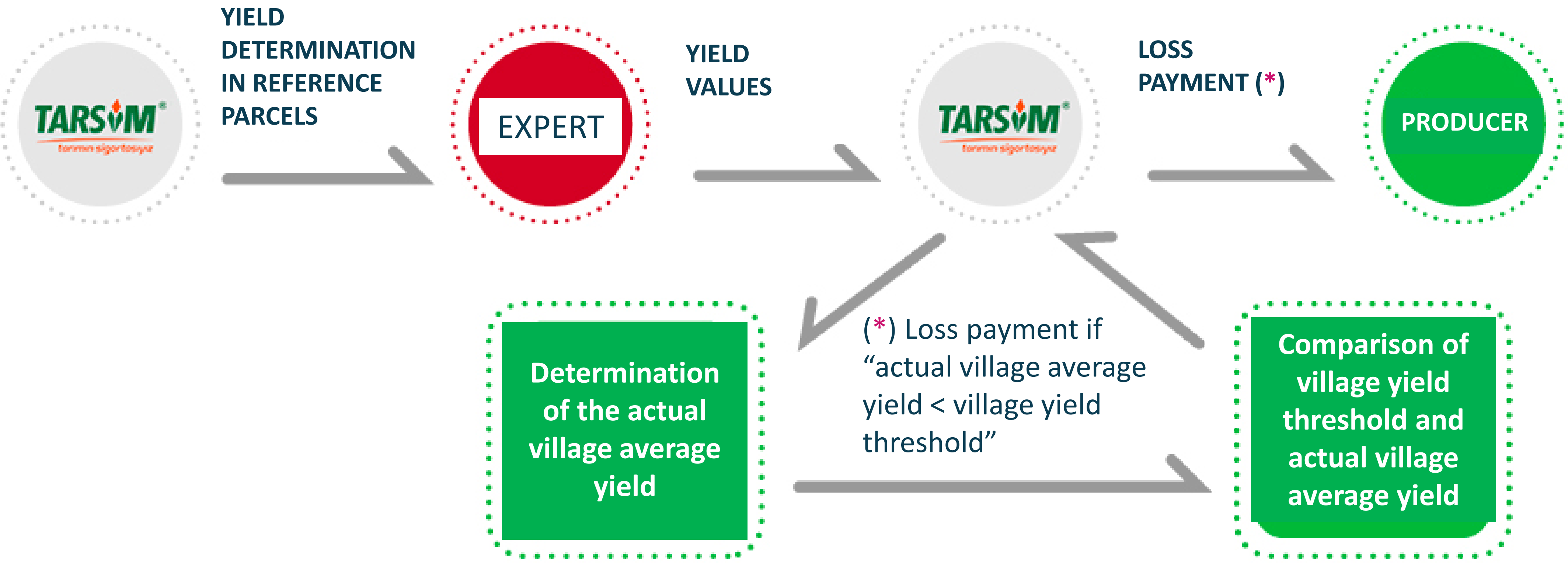
The concept of climate resilience in terms of risk/uncertainty perception: A survey study

Other important results of the survey:

- Among the sources of risk, the **input market has the biggest influence, followed by weather and natural disasters and price.**
- Producers who have a **higher income** and are **more satisfied with their farming practices tend to take greater risks**. It is obvious that **lower levels of risk-taking are correlated with higher levels of use of different risk reduction techniques**.
- It is noted in this study that **farmers anticipate larger loss frequencies** (an average of 5.09/10) in the future whereas loss occurred **less frequently in the past** (an average of 3.29/10) despite the fact that 68.6% of the farmers stated that they could adapt to the risk by doing something to reduce the impact of the realized risk. **This demonstrates our claim that the surveyed farmers perceive risk and uncertainty differently.**

Actuarial insights into parametric insurance

Loss process in *“village-based drought yield insurance”*



PROBLEMS:

- how the village yield threshold is determined
- the moral hazard/adverse selection caused by the farmer's perception of risk/uncertainty

Key features of parametric insurance

- Parametric insurance, or index insurance, is a type of insurance contract wherein the insurer agrees to pay an **ex-ante agreed amount** on a scheduled basis once **a parameter or index reaches a threshold specified by the contract**.

- Two **key parts** of contracts based on parametric insurance:
  1. **A trigger:** Pre-defined parameter or index value which means that the insurance will pay out if an event reaches the specified trigger level.
  2. **Pay-out scheme:** The amount paid to the insured in the event that hits the trigger level

Advantages and challenges of parametric insurance

- **Advantages** of parametric insurance (Radu and Alexandru, 2022):
  - The reimbursement happens immediately, and payment is paid out quickly;
  - Payment is assured if the event occurs (**immune to moral hazard**);
  - Products could be customized based on the characteristics of the risk.

- **Challenges** of parametric insurance for pandemics (Figueiredo et al., 2018; Lin and Kwon, 2020):
  - It is necessary to employ an **objective and transparent trigger optimization** process (for instance a probabilistic framework for parametric trigger modeling).
  - **Basis risk** is the difference between the payment based on the parameter/index (or the loss model) and the actual loss of the insured.
    - **Positive basis risk:** The differences that occur when an insurer pays claims to insureds that are not impacted by a loss event or when the payout exceeds the actual loss. The insurer's **insolvency risk** could be influenced.
    - **Negative basis risk:** The differences that occur when an insured party experiences a financial loss as a result of a covered occurrence and the insurer either fails to pay their claim or pays less than the actual loss. It implies insurer's reputational risk.

Traditional insurance vs parametric insurance

- Unlike traditional indemnity-based insurance, which depends on estimates of losses after an event, parametric insurance covers the probability of the occurrence of a **predefined event** and makes payment in accordance with a **predetermined plan**.
- Since parametric insurance enables insurers to significantly lower their underwriting and claim assessment costs, it can serve as an additional layer of coverage to close the **protection gap (***the difference between insured losses and economic losses*) in traditional insurance (Lin&Kwon, 2020).
- **Fast claim settlement** has importance over accuracy in claim handling procedures because parametric insurance does not require the identification of losses or the justification of compensation spent, unlike traditional indemnity-based insurance, where payments are linked to actual losses or damage (Radu and Alexandru, 2022).

What is “climate-resilient parametric insurance”?

- Parametric insurance provides protection for **vulnerable populations** in emerging economies against extreme weather events and natural disasters when traditional insurance is too **expensive or impractical**, while also removing concerns about **moral hazard and adverse selection** (Lin and Kwon, 2020).
- Even though it is well known that there are obstacles to overcome in order to **integrate climate resilience into parametric insurance schemes**, including those related to **funding constraints and policy implementation**, parametric insurance can contribute to a strong portfolio of solutions to climate risk if the innovation system is strengthened as a whole (Hellmuth et al., 2009).
- **How to make parametric insurance sustainable?**
  - Climate-resilient measures can **positively** impact parametric insurance.
  - **Lowering the probability of triggering insurance payouts** through resilience measures can lead to **reduced premiums** for insured parties.
  - **Climate-resilient infrastructure can decrease the frequency and severity of claims**, making parametric insurance more sustainable for insurers.

Actuaries Climate Index (ACI)

- **The Actuaries Climate Index (ACI),** which integrates data from several major weather factors, was developed by actuaries to support insurers in **identifying and managing emerging risks related to climate change.**
- The ACI, which is led by actuarial organizations, is an **innovative and reputable tool** that will be used in risk management procedures, actuarial practice, research projects, and public education regarding **climate change** (Patten and Zhou, 2023).
- The ACI was launched in North America and Australia and is being built in Europe, the United Kingdom, India, Turkey, and Iberian Peninsula (Curry, 2015; ACI, 2018; AACI, 2018; Kotnala et al., 2018; Nevruz et al., 2022; Zhou et al., 2023).
- The ACI might offer actuaries trustworthy data on **"extreme" weather events**, which is crucial for calculating and simulating insurance and financial risks associated with climate change (Pan et al., 2022).
- The insurance business has acknowledged that **human health, mortality, and morbidity** are also tied to climate change, in addition to **property losses** caused by natural disasters since the **relationship between insurance and climate variables** could be formalized (Carriquiry and Osgood, 2012; Miljkovic et al., 2018).

The ACI as a compound index

- The trend in structured standardized climate indices *(such as Normalized difference vegetation index-NDVI)* focuses on **"average"** changes over a given period.
- Instead of average climate change, the data sets used to develop the ACI are considered to assess the **"risk"** posed by climate change, which denotes the **"frequency of severe climate changes"**. **Standardized anomalies** are used in the calculation of the ACI.
- Various climate factors that represent extreme weather are used in the ACI.

Indicator	Abbreviation	Definition
High temperatures	$T90$	Temperature frequencies above the 90th percentile
Low temperatures	$T10$	Temperature frequencies below the 10th percentile
Heavy rainfall	P	Maximum monthly rainfall for five consecutive days
Drought	D	Maximum consecutive dry days in a year
High wind	W	Wind speed frequencies above the 90th percentile
Sea level	S	Changes in sea level

$$ACI = \text{mean}(T90_{std} - T10_{std} + P_{std} + D_{std} + W_{std} + f_S S_{std})$$

- The change in the frequency of warmer temperatures above the 90th percentile and colder temperatures below the 10th percentile (T10), relative to the reference period, are referred as the **extreme temperature components** where X (N) is used for maximum (minimum) temperature variable.

$$T90_{\text{std}} = \frac{1}{2}\left(\frac{TX90 - \mu_{\text{ref}}(TX90)}{\sigma_{\text{ref}}(TX90)} + \frac{TN90 - \mu_{\text{ref}}(TN90)}{\sigma_{\text{ref}}(TN90)}\right) \text{ and } T10_{\text{std}} = \frac{1}{2}\left(\frac{TX10 - \mu_{\text{ref}}(TX10)}{\sigma_{\text{ref}}(TX10)} + \frac{TN10 - \mu_{\text{ref}}(TN10)}{\sigma_{\text{ref}}(TN10)}\right)$$

- The highest 5-day rainfall (Rx5day) in the month, which measures flood risk (P), and the highest number of consecutive dry days (CDD) in a year with less than 1mm of daily precipitation, which measures drought (D), are the **components of precipitation**.

$$P_{\text{std}} = \frac{Rx5\text{day} - \mu_{\text{ref}}(Rx5\text{day})}{\sigma_{\text{ref}}(Rx5\text{day})} \text{ and } D_{\text{std}} = \frac{CDD - \mu_{\text{ref}}(CDD)}{\sigma_{\text{ref}}(CDD)}$$

- The daily wind speed (w) is converted to wind power (WP) since the **effects of strong winds**, i.e. damages, are proportional to WP rather than to w. Lastly, **sea level** (S) component evaluates the combined influence of the generally rising seas and the rising/dropping land on coastal shorelines (f_S: the percentage of coastal grid points relative to all grid points in a region)

$$W_{\text{std}} = \frac{WP90 - \mu_{\text{ref}}(WP90)}{\sigma_{\text{ref}}(WP90)} \text{ and } S_{\text{std}} = \frac{S - \mu_{\text{ref}}(S)}{\sigma_{\text{ref}}(S)}$$

The Turkish Actuaries Climate Index (TrACI)

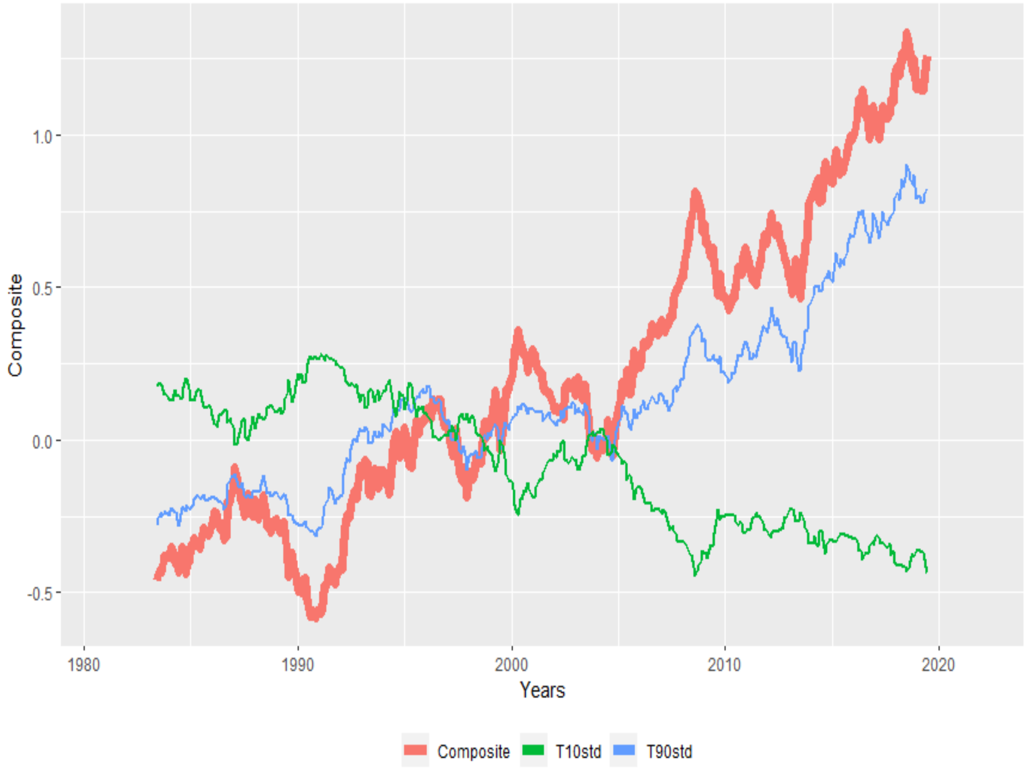


Figure 1. The five-year moving average of standardized anomalies of high and low temperatures and their composite indicator

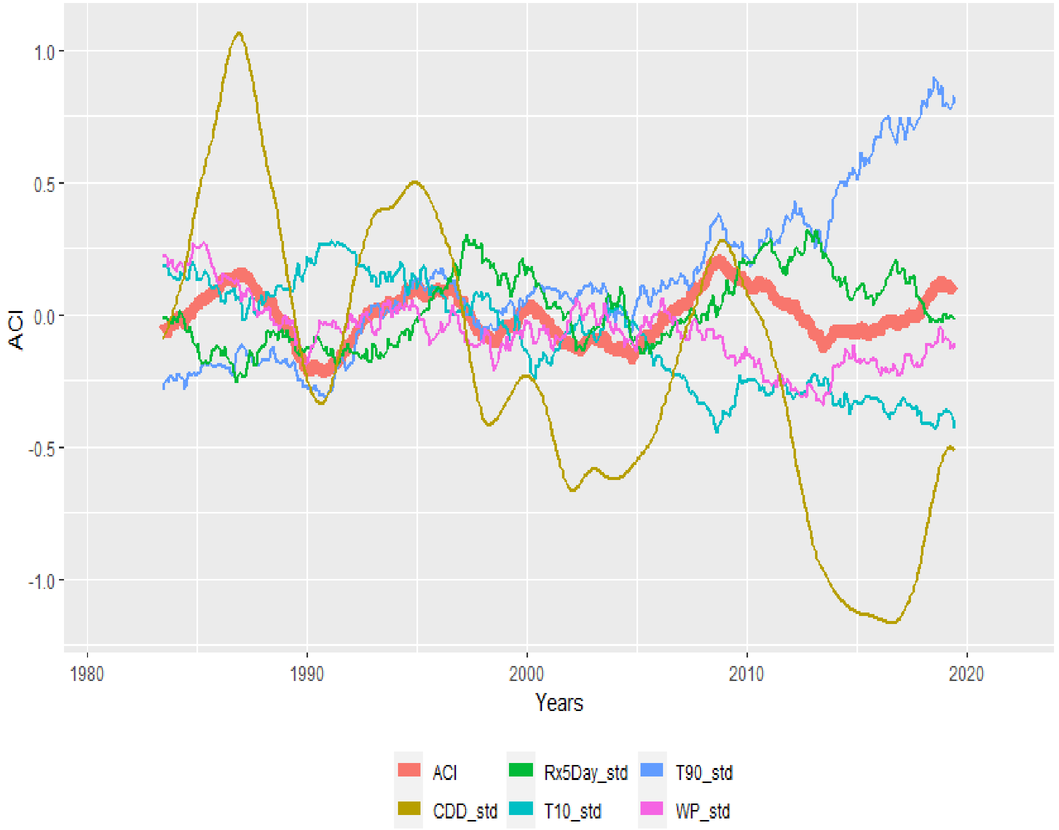


Figure 2. The five-year moving average of the ACI and its components for Ankara

The ACI as a candidate for “trigger”

- When the effectiveness of ACI on insurance products is investigated, models are developed to assess and anticipate agricultural losses for crop insurance and reinsurance applications, and it is also found that the ACI significantly predicts the impact of climate change on business revenues (Jiang and Weng, 2019; Pan et al., 2022).

- The suggested benefit formula in a parametric insurance relying on the trigger ACI can be formulated as follows:

$$\boldsymbol{b} = \begin{cases} \boldsymbol{I} \,; \boldsymbol{Y} < \boldsymbol{f}(\boldsymbol{ACI}) \\ \boldsymbol{0} \,; \textbf{otherwise} \end{cases}$$

where b is the benefit amount, I is the indemnity amount, Y is the yield amount and $f(.)$ is a predetermined model that indicates the effect of interrelations among the ACI’s components on yield.

Challenges and suggestions

- **Challenges:**
  - **Data quality** (Low concentration of weather stations, e.g. Eastern Europe and Russia for temperature data, etc.)
  - **Cost** (actual/estimated costs of developing and updating the ACI)
- **Suggestions:**
  - Choosing the best **grid dataset** for the ACI is more important than changing how the index is calculated (Nevruz et al., 2022).
  - Insurance firms will have a precise tool for estimating climate risk when relevant **cell subsets are merged** to analyze extreme climate trends at a **higher resolution, more localized level** (Zhou et al., 2023).

Challenges and suggestions

- The ACI will be subject to **regular review and potential change**.

- **ACI's sustainability?**
  - User demands for flexibility
  - Changes/improvements in data availability
  - Compatibility with other indices
  - Transition to a global index
  - Development of a risk index (Actuarial Climate Risk Index-ACRI)

Sustainability: Future Directions and Conclusions
ESG: Nature-Based Solutions

- **Nature-based solutions:** Utilizing **natural capital**, i.e. ecosystem services
  - Transition from **monoculture to polyculture**
  - **Regenerative agriculture:** ancient methods in agriculture
  - **Agroecology**
  - **Permaculture**
  - Biotechnology

Loess Plateau (Source: The World Bank Institute)

Sustainability: Future Directions and Conclusions
ESG: Human-Based Solutions

- **Human-based solutions:** The inclusion of **human capital** in ESG
  - Transition from **market economy to solidarity economy**
  - **Definition of labor:** seasonal workers, local people, disadvantaged groups
  - Risk sharing and community resilience
  - Partnerships and collaboration

wellcertified.com

Sustainability: Future Directions and Conclusions
ESG: Policy-Based Solutions

- **Policy-based solutions:** Regulatory frameworks and policies related to **innovative parametric insurance**
  - Innovation in insurance products that support **resilience and environmental sustainability is encouraged** by the solidarity economy.
  - Examples include **parametric insurance linked to ecosystem health indicators**, green bonds for financing nature-based solutions, or microinsurance products tailored to support sustainable agriculture or fisheries.
  - Insurers can collaborate with solidarity economy initiatives to co-develop insurance solutions that address **community needs while promoting environmental sustainability**.

References

1. ACI (2018), Actuaries Climate Index: Development and Design, *the American Academy of Actuaries, the Canadian Institute of Actuaries, the Casualty Actuarial Society, and the Society of Actuaries*, Available online: https://actuariesclimateindex.org/wp-content/uploads/2019/05/ACI.DevDes.2.20.pdf (accessed on 21 October 2022).
2. AACI (2018), Design Documentation: Australian Actuaries Climate Index, November 2018, Available online: https://actuaries.logicaldoc.cloud/download-ticket?ticketId=52034b4d-5c50-4bff-b4d7-05e084d2fc42 (accessed on 21 October 2022).
3. Carriquiry, M. A. and Osgood, D. E. (2012). Index Insurance, Probabilistic Climate Forecasts, and Production. *Journal of Risk and Insurance*, 79(1), 287-300.
4. Curry, C. L. (2015). Extension of the Actuaries Climate Index to the UK and Europe: A Feasible Study*, Institute and Faculty of Actuaries*, December 2015.
5. FAO (2023), *Developing Alternatives for Agricultural Risk Management for Small Farmers in Agri-Food Value Chains,* Project, FAO Türkiye (Food and Agriculture Organization Türkiye) & The Union of Chambers and Commodity Exchanges of Türkiye (TOBB) , May 2022-March 2023.
6. Figueiredo, R., Martina, M. L., Stephenson, D. B., and Youngman, B. D. (2018). A probabilistic paradigm for the parametric insurance of natural hazards. *Risk Analysis*, 38(11), 2400-2414.
7. Hansen, J., Sato, M., Glascoe, J. and Ruedy, R. (1998). A Common-Sense Climate Index: Is Climate Changing Noticeably?. *Proceedings of the National Academy of Sciences*, 95(8), 4113-4120.
8. Hellmuth M.E., Osgood D.E., Hess U., Moorhead A. and Bhojwani H. (eds) (2009). Index insurance and climate risk: Prospects for development and disaster management. *Climate and Society* No. 2. International Research Institute for Climate and Society (IRI), Columbia University, New York, USA.
9. Jiang, R. and Weng, C. (2019). Climate Change Risk and Agriculture-Related Stocks. *Available at SSRN:* http://dx.doi.org/10.2139/ssrn.3506311.
10. Kotnala, R., Jain, S. and Ankolekar, M. (2018). Introduction to an International Actuarial Climate Index: An Indian Showcase, *Institute and Faculty of Actuaries (IFoA),* Asia Conference 2018.

References (*continued*)

11. Lin, X., and Kwon, W. J. (2020). Application of parametric insurance in principle-compliant and innovative ways. *Risk Management and Insurance Review*, 23(2), 121-150.
12. Miljkovic, T., Miljkovic, D. and Maurer, K. (2018). Examining the Impact on Mortality Arising from Climate Change: Important Findings for the Insurance Industry. *European Actuarial Journal*, 8(2), 363-381.
13. Nevruz, E. (2018). *Multivariate stochastic prioritization of dependent actuarial risks under uncertainty (Ph.D. Thesis)*, Department of Actuarial Sciences, Graduate School of Science and Engineering, Hacettepe University, Ankara, Turkey.
14. Nevruz, E., Atıcı, R. Y., and Yildirak, K. (2022). Actuaries Climate Index: An Application for Turkey. *İstatistik Araştırma Dergisi (Journal of Statistical Research)*, 12(2), 14-25.
15. Pan, Q., Porth, L. and Li, H. (2022). Assessing the Effectiveness of the Actuaries Climate Index for Estimating the Impact of Extreme Weather on Crop Yield and Insurance Applications. *Sustainability*, 14(11), 6916, 1-24.
16. Patten, M., and Zhou, K. Q. (2023). Current and Potential Uses for the Actuaries Climate Index: How to Move Forward. *Society of Actuaries Research Institute*.
17. Radu, N., and Alexandru, F. (2022). Parametric insurance – a possible and necessary solution to insure the earthquake risk of Romania. *Risks*, 10(3), 59.
18. Shen, S., Benedetti, M. H., Zhao, S., Wei, L., and Zhu, M. (2020). Comparing distance and time as driving exposure measures to evaluate fatal crash risk ratios. *Accident Analysis & Prevention*, 142, 105576, 1-8.
19. Wilkes, M., Long, G., Massey, H., Eglin, C., and Tipton, M. (2022). Quantifying risk in air sports: Flying activity and incident rates in Paragliding. *Wilderness & Environmental Medicine*, 33(1), 66-74.
20. Yuill, G. M. (1977). Icarus's syndrome: New hazards in flight. *British Medical Journal*, 1, 823-825.
21. Zhou, N., Vilar-Zanón, J. L., Garrido, J., and Heras Martínez, A. J. (2023). On the definition of an actuarial climate index for the Iberian Peninsula. *Anales Del Instituto De Actuarios Españoles (Annals of Spanish Institute of Actuaries)*, (29), 37-59.

Thank you

Contact Details

Department of Actuarial Sciences, Faculty of Science, Hacettepe University, 06800 Çankaya/Ankara/Türkiye

ezginevruz@hacettepe.edu.tr
https://orcid.org/0000-0002-1756-7906