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The network of experts on machine learning and the climate change challenge[1]

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The Network of Experts on Machine Learning and the Climate Change Challenge

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The hackathon *Climate Change Challenge* was held at the European Central Bank from the 14th to the 16th of November 2023 and was co-organised by the European System of Central Banks' (ESCB) Network of Experts in Machine Learning. The event gathered 64 participants from 26 ESCB or Single Supervisory Mechanism (SSM) entities around the common topic of using machine learning techniques and granular climate data to improve the understanding and the assessment of the impacts of drought and heat stress on the gross value added in the agricultural and manufacturing sectors. This short paper focuses on the outcome of the hackathon, the lessons learned, and the follow up initiatives on enhancing the use of Machine Learning in central banking statistics.

Keywords: machine learning, hackathon, drought, heat waves, gross value added
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Contents

Introduction 3

1. Objectives of the hackathon 3
   - Description of the topic 3
   - Description of the datasets 4
2. Organisation of the event 5
   - Organisation team 5
   - Composition of the teams 6
   - Evaluations of the deliverables 6
3. Results and next steps 6

Introduction

The ESCB/SSM Network of Experts on Machine Learning has emerged from the Task Force on Machine Learning in 2020. The network is open to all members of institutions in the ESCB and SSM with an interest in the field of machine learning or a business need to investigate and implement machine learning solutions. The network is mandated to foster an exchange of knowledge and best practices as well as to support joint projects. One of the main activity in 2023 in the agenda of the Network was the organization of a climate change hackathon. The aim of such a hackathon was to bring together diverse talents and create tangible solutions that could potentially be implemented by central banks and financial institutions to better address climate-related risks and opportunities in their operations and policies.

The hackathon *Climate Change Challenge*[1] was held at Frankfurt from the 14th to the 16th of November 2023. This event gathered 64 participants from 26 European SEBC or SSM entities around a common topic, namely how machine learning techniques and granular climate data can help to improve our understanding and the assessment of the impacts of drought and heat stress on the gross value added in the agricultural and manufacturing sectors. The participants were split into 8 teams and had 24 hours to develop concrete solutions addressing this challenging topic.

After 24 hours of intensive work, each team had to present their main results to a panel of technical experts and a jury composed of representatives from the ECB, the Banca d'Italia, the Banque de France, and the Copernicus Emergency Management Service (CEMS) run by the Joint Research Centre of the European Commission (JRC). Results obtained during this very short time were encouraging. They already revealed how climate data can help improve the forecasting of macro-economic variables in climate sensitive sectors as well as some avenues to enrich the set of relevant climate indicators that were drawn by the winning teams.

These results, obtained by the winning team, will be further explored in the future. Especially, a collaboration between the top team and experts from the ECB and CEMS is envisaged to expand the research which could be ultimately be published as a scientific paper in a journal in interdisciplinary sciences.

1. Objectives of the hackathon

Description of the topic

Climate extremes such as heat waves, droughts, floods, forest fires and wind storms can negatively affect human wellbeing, ecosystems, different economic sectors and assets. Climate change is expected to bring increasing frequency and intensity of climate extremes, posing growing risks to society and economy. As such, better understanding of climate extremes, their compounding effects and their implications

[1] https://innovation.banque-france.fr/fr/challenges/climate-change-challenge-banque-france-ecb?lang=en

on non-financial enterprises is essential for a better assessment of climate change related risks for financial institutions, which add up to traditional risk.

This hackathon focused in particular on two highly impactful climate extremes:

- Droughts: prolonged period of time when an area or region experiences below-normal available water due to several factors such as precipitation deficit and higher than usual temperatures;
- Heat waves: extended periods with unusually very high temperatures.

Drought and heat waves often lead to significant socio-economic impacts, as indicated by a growing body of literature. The most important sectors affected by drought and heat stress include public health, agriculture, food production, energy, and river transport. Reported financial losses range between several hundred millions to several billions €.

Further exploration and better understanding of acute physical risks stemming from droughts and heat waves are essential for financial institutions to avoid blind spots to major risks. Using Machine Learning (ML) techniques increasingly applied in the fields of earth system sciences and economics, the participants were asked to disentangle the effects of these two climate phenomena on the gross value added in the agricultural and manufacturing sectors in Europe.

The focus of the participants was primarily on the following steps:

- Using ML methods in explanatory data analysis, revealing patterns and importance of different features and characteristics of the data (i.e. answering questions on which factors are important and why); in particular, uncovering spatially dependent patterns of macro-economic dependency on drought and heat stress.
- Creating a model with the best predictive power; in particular, in predicting the impact of droughts and heat waves on the gross value added in the agricultural and manufacturing sectors in Europe. The patterns deriving from the first step could be used to feed predictive models.

The models developed had to be spatially dependent, as the production in the agricultural and manufacturing sectors varies across different countries/regions and responds differently to climate shocks.

Description of the datasets

The participants were free to choose any machine learning methods to reach these two objectives with at their disposal two sets of data:

- Annual granular macro-economic variables at NUTS-3 level from National Accounts in the "General and regional statistics" of the Eurostat Database:
    - Sectoral gross value added;
    - Number of employed persons by sector;

- Gross domestic product;
- Population;
- Area of the region.

- Drought and heat waves granular indicators pre-processed at NUTS-3 level from raw data made available by the CEMS European Drought Observatory:
  - Standardized Precipitation Index (SPI) computed on a range of time scales (1 month, 3 months, 6 months and 12 months). SPI characterizes the deviation of total cumulated precipitation from the long-term average on a pre-defined temporal scale. Precipitation data are derived from the ECMWF ERA5 reanalysis.
  - Soil Moisture Anomaly (SMA) characterising the soil conditions in terms of water and derived from the hydrological Lisflood model simulations;
  - Low flow index charactering rivers' conditions and derived from the hydrological Lisflood model simulations;
  - Fraction of Absorbed Photosynthetically Active Radiation (FAPAR) derived from remote sensing data (Modis);
  - Heat Wave Index (HWI) characterising the energy surplus during a heat wave derived from the ECMWF ERA5 daily temperature;
  - Monthly Average of Maximum Daily Temperatures (TMAX) derived from the ECMWF ERA5 reanalysis.

Besides, each team had at their disposal a dedicated development environment on an ECB cloud platform.

2. Organisation of the event

Organisation team

Originally proposed by data science experts from the Banca d'Italia to the Network of Experts on Machine Learning, the organization team of the event gathered agents from different fields from the ECB[2], the Banca d'Italia[3], the Banque de France[4] and the support and help of the JRC[5] (European Commission) which provided the climate datasets.

[2] Z. Hofmeister (Data science/statistics – NoE on ML), A. Ceglar (Climate science), F. Ben Meradi (HR), G. Fischer (HR), G.Marcari (IT).

[3] S. Marchetti (Data science), M. Loberto (Data science), F. Monacelli (Data science/Statistics).

[4] A. Le Douaron (Lab team), E. Burdeau (Data science – NoE on ML).

[5] A. Toreti (Climate science)

Composition of the teams

This hackathon gathered at Frankfurt 64 participants from 26 European institutions coming from 23 countries. The participants were allocated by the organization team into 8 teams to have balanced skills in data science, statistics, computer science, climate science in each team and a balanced representation of the different institutions/countries and native languages.

Evaluations of the deliverables

The deliverables proposed by each participating team were evaluated in two steps. First, the data science and climate science experts from the organization team evaluated the technical aspects of the work done (model performance, explainability of models and results, quality and soundness of the code). Afterwards each team had 10 minutes to sum-up their work to a jury composed of representatives of the ECB (I. Heemskerk, A. Bonara), the Banca d'Italia (S. Vori), the Banque de France (L. Clerc) and JRC (A. Toreti). The jury assessed the teams' results with a focus on policy relevance and valorisation of climate data.

3. Results and next steps

The Key Outcomes of the event were:

- Innovative solutions: The hackathon produced a range of tools and applications addressing climate-related challenges in the financial sector:
    - Data Visualization: Several projects emphasized creating user-friendly dashboards and interactive visualizations to make complex climate data more accessible and understandable. The winning projects emphasized the importance of creating intuitive, easy-to-use interfaces for climate risk assessment and scenario analysis.
    - ML Applications: Teams leveraged artificial intelligence and machine learning techniques to analyse complex climate data and predict potential risks and impacts.

- Data utilization: Participants effectively leveraged various datasets, including those from the Copernicus European Drought Observatory to develop their solutions. The hackathon highlighted the need for high-quality, accessible climate-related data for developing effective solutions.
- Interdisciplinary collaboration: The event brought together diverse expertise, combining financial knowledge with data science and climate science. The event demonstrated the benefits of bringing together diverse stakeholders to address climate-related challenges in finance. In addition, the hackathon revealed the potential for continued innovation in integrating climate considerations into financial decision-making and risk management.

- Integration of climate information: Many submissions sought to integrate climate-related factors into existing financial models and decision-making processes.

Other relevant themes emphasized by the hackathon teams were:

- Climate Risk Assessment: Many projects focused on developing tools and methodologies to assess and quantify climate-related risks for financial institutions and businesses.
- Scenario Analysis: Submissions included models and applications for conducting climate scenario analysis, helping organizations understand potential future impacts of climate change.
- Green Finance: Some submissions focused on promoting and facilitating sustainable investment and financing options.
- Policy Impact Analysis: Projects aimed at assessing the potential impacts of climate policies on various economic sectors and financial markets.

These themes reflect the hackathon's goal of developing innovative solutions to address climate-related challenges in the financial sector, with a particular focus on risk assessment, data analysis, and decision-making tools.

The 3 winning teams demonstrated remarkable collaboration and great preliminary preparation of climate data. In particular, the winning team proposed additional climate indicators to the initial climate dataset provided by using geographical information to create indicators on neighboring regions and borders but also looking at joint effect of climate variables and persistent effects of climate extremes.

On the machine learning side, a common approach was the boosting techniques to predict the gross value added in the agricultural and the manufacturing sectors and the use of SHAP (SHaply Additive exPlanations) to explain how each feature contributes to the variation of the gross value added.

At last, the preliminary work carried out by winning team on climate data was crucial to observe significant impact of climate data on the gross value added in the agricultural and manufacturing sectors when incorporating variables into both predictive models and explanatory data analysis.

The next steps for further analysis that the hackathon organizers and participants identified are:

- Further Development: The winning teams will have the opportunity to continue developing their projects with support from the organizing institutions. This ongoing collaboration aims to refine and enhance the solutions created during the hackathon.
- Potential Integration: There is a possibility that some of the innovative solutions developed during the challenge could be integrated into the operations of the Banque de France, the ECB, or other financial institutions. This integration would help put the ideas into practical use.

- Continued Innovation: The hackathon has set the stage for continued innovation in addressing climate-related challenges in the financial sector. The ESCB/SSM community would encourage further research and development in this area.
- Knowledge Sharing: The insights and solutions generated during the hackathon will be shared within the community, potentially inspiring new approaches to climate risk assessment and management.
- Future Events: the success of this hackathon may lead to similar events in the future, fostering ongoing collaboration between the ESCB/SSM, financial institutions, tech innovators and climate experts.

These next steps demonstrate a commitment to turning the hackathon's innovative ideas into practical solutions for addressing climate change challenges in the financial sector.

Besides, the preliminary results obtained by the winning team[6] will be further explored. Especially, a collaboration between the top team and experts from the ECB and JRC is envisaged to expand the research which could ultimately be published as a scientific paper in a journal in interdisciplinary sciences. Finally, other initiatives such as an extension of this first hackathon by the Banque de France are currently under study.

[6] N. Vorderobermeier (BBK), S. Spiteri (CBM), L. Lebouteiller (BCL), J. Willequet (NBB), NBS (M. Volesini), S. Bonev (BNB), J. Blixt (RB), M. Delgado Tellez (ECB).

EUROPEAN CENTRAL BANK
EUROSYSTEM

Network of Experts on Machine Learning

Climate Change Challenge

23/08/2024

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Introduction

The ESCB/SSM Network of Experts on Machine Learning created in 2020 was mandated to foster an exchange of knowledge and best practices as well as to support joint projects on Machine Learning.

Among its initiatives, the Network organized the **Climate Change Challenge,** a hackathon co-organised by the ECB, the Banca d'Italia, the Banque de France and the Copernicus services of the European Commission.

Link to the official website

The organisation team was coordinated by the ECB and composed of experts from Machine Learning and Climate Change as well as hackathon organisers.

This **physical event took place at the ECB from the 14th to the 16th of November 2023**

After some coaching sessions during the first afternoon, participants to the event had **24 hours to answer to a specific question**.

Scope of the Hackathon (1/2)

Main question to answer in 24 hours:

What is the impact of droughts and heat stress on industrial and agricultural added value?

With 2 guiding principles:

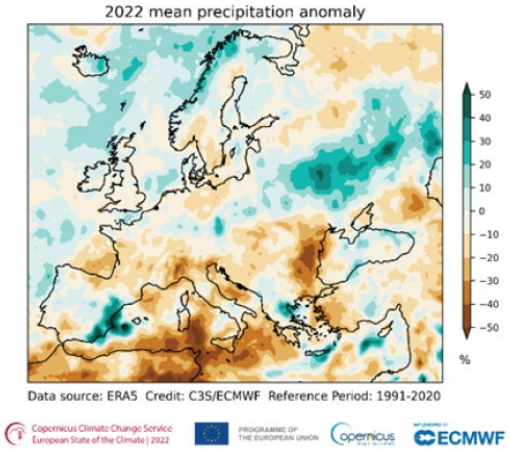
- **Explain** – reveal patterns and importance of different features and characteristics of the data (which factors are important and why);

- **Predict** – predict the impact of drought and heat stress on industrial and agricultural production.

Scope of the Hackathon (2/2)

Relying on time series of:

- **Macro-economic data from Eurostat at NUTS3 level** as target variables (sectoral gross value added) but also as control variables (employment, population, GDP) ;
- **Climate data from the European Drought Observatory** (Copernicus services – EC) **as explanatory variables**:
  - Standardized Precipitation Index;
  - Soil Moisture Anomaly;
  - Low Flow Index;
  - Fraction of Absorbed Photosynthetically Active Radiation;
  - Heat Wave Index;
  - Monthly Average of Maximum Daily Temperatures.



The participants had at their disposal AWS Cloud platform to execute and share programs within teams.

Composition of the teams

64 participants to the event were allocated to **8 teams**.

The composition of each team took into account that:

- Participants were from **26 institutions** and 23 countries;
- Participants had **different backgrounds**: data science, statistics, computer science, economics, macro/micro prudential risks, climate risks, climate science, …

The composition of each team was determined by the hackathon organisation team considering **some allocation criteria**.

Evaluation of the winning teams

The evaluation of the winning teams was carried out in 2 steps:

- **A first evaluation** on detailed technical review of the notebooks and assessment of the results **by a panel of 5 experts** (Machine Learning and Climate change);

- **An assessment of the teams' results**, with a focus on policy relevance **by High-level jury** (ECB – DGS & CCC, BdI, ACPR, Copernicus).

After deliberation of the Jury and the panel of experts, three winning teams were selected. Prizes were awarded by the President of the ECB.

Results and next steps (1/2)

Beyond fruitful discussions on machine learning techniques and data visualization to policy impact analysis and integration of climate considerations into existing models as well as climate risk assessment, **key results of this hackathon** were:

- **Interdisciplinary collaboration** foster new ideas for climate-related challenges in finance;
- Tangible avenues for **relevant climate indicators** built upon granular climate data from Copernicus services;
- Using ML techniques, heat waves and droughts have a **significant impact on the gross value added** in the agricultural and manufacturing sectors.

Results and next steps (2/2)

Next steps beyond the time frame of the hackathon were:

- **Further development and potential integration**: the top winning team collaborates with the ECB and the Copernicus services to expand their research;
- **Knowledge sharing**: the results obtained by the different teams were shared on a collaborative platform;
- **Continued Innovation and future events**: The encouraging results obtained during the hackathon could be enriched with complementary climate datasets and improved with advanced ML techniques;