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The Added Value of Seasonal Climate Forecasting for Integrated Risk Management

Assessing Economic Value to Support Management Decisions

Nicholas Vasilakos
University of East Anglia

University of East Anglia
Italian national agency for new technologies, energy and sustainable economic development
Met Office
AWS TRUEPOWER
WEMC World Energy & Meteorology Council
eurac research
alperia

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The Added Value of Seasonal Climate Forecasting for Integrated Risk Management

- Why assess economic value of seasonal forecasting?
  - Provides a tangible measure of user benefits
  - Enables comparisons between different scenarios/options
  - Helps to proxy price of «new information» and likely economic returns
- Studies on value of climate information services have mainly focused on agriculture/farming in the past
  - See deliverable 1.4 for a review of the literature
  - Other relevant studies include Clements et al. (2013); Bruno Soares (2018); Bosello et al. (2018)
- We look at case studies (energy/water management/maintenance/system balancing) to evaluate the benefits of the optimised seasonal products and compare them to alternatives (e.g. climatology).

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Climate Services examples

http://www.cmcc.it/climateservice/

CLIMATE

Sea level rise
Ocean circulation
Drought
Extreme Events
Temperature
Heat waves
Wind
Seasonal Forecast
Tropical cyclones
Precipitations
Currents
Waves

IMPACTS

Water quality
Costal Erosion
Ship routing
Floods
Food security
Agriculture
Landslide
Oceans
Oil spill
Forestry
Water scarcity
Risk Analysis
Vulnerability assessment
Land Degradation
Carbon Cycle
Crop Modelling
Wild Fires

ECONOMY & SOCIETY

Economic Assessment
Adaptation plans
Mitigation and Adaptation Policies
Cost Benefit analysis
Socio-Economic modelling
Policy impacts & costs

WP1: Modelling Options for Value-Add Assessment

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MENU

MENU OF ECONOMIC ASSESSMENT METHODS

- ****DECISION THEORY MODELS****
- ****AVOIDED COSTS****
- ****ECONOMETRIC MODELS****
- *CONTINGENT VALUATION APPROACHES*
- PARTIAL AND GENERAL EQUILIBRIUM MODELS
- ALTERNATIVE METHODS

*How are weather-related **decisions** currently made in our project **Case Studies**?*

*Which **Economic Assessment methods** are used, or could be used, to assess and support those **decisions**?*

*How can we use those methods to **quantify the potential benefits** of using **seasonal forecasts?***

*What can we **learn** from each other across **Case Studies**, **Areas** and **Sectors**?*

Decision theory models: optimization of an objective function by a single agent whose decisions have no effect on market/sector/economy.

Key assumptions:

- Fully rational, risk-neutral decision-maker constrained by access to information.
- Agent seeks to maximise benefit (expected utility models) or minimise costs (cost-loss models)
- Market demand and supply remain unaffected by the choices of the agent.

Expected utility models

$$EVOI = E\{U[Y(X_f), W_0]\} - E\{U[Y(X^*), W_0]\}$$

X_f : with improved foresight (e.g. due to seasonal forecasting)

X^*: without improved foresight (base case)

W_0: industry’s initial level of wealth, affecting the shape of the utility function (together with risk aversion).

Decision theory models: optimization of an objective function by a single agent whose decisions have no effect on market/sector/economy.

Examples:

(1) Power generation/system balancing: optimized dispatch due to improved forecasts, which may result in higher profits for power utility.

(2) Hydroelectric generation: improved water management

Decision theory models: applications

- Everingham et al. (2012) evaluate the effect of using climate forecast models on revenues for the Herbert sugarcane region in Australia. They estimate the added value of such forecasts to be in the region of AUD$1.9M per year.
- Hamlet et al. (2002) estimate that use of climate forecasts in the management of hydroelectric dams on the Columbia River can increase energy production by 5.5 million MW/hour/year, which corresponds to an increase in net revenues in the region of US$153M.
- Ritchie et al. (2004) use a case study from eastern Australia to show that availability of climate forecasts does not necessarily result in improvements in actual outcomes. Their results show that expected outcomes can differ significantly from simulated outcomes that assume perfect foresight. Their work highlights the importance of considering forecast accuracy from a user perspective.

Avoided Costs: value of information (i.e., the seasonal forecast) is calculated as the total value of all costs that would have been incurred if the forecast was not available/used.

Examples:

(1) Power utilities tend to ramp up production when they expect higher temperature. Better quality forecasts result in smaller forecasting error and, therefore, cost savings.

(2) Water utilities can suffer damages in their infrastructure as a result of extreme weather (Danilenko et al. 2010; they describe this as one of the biggest challenges that water utilities are faced with as a result of climate change)

(3) Offshore maintenance: lower hiring costs for vessels

Avoided Costs models: applications

- Frei et al. (2012) find that the use of weather services by the transportation sector in Switzerland would result in $56.1M to $60.1M in avoided costs in the form of lower governmental spending.
- Liao et al. (2010) estimate the value of ENSO information in the Northern Taiwan regional water market to be as high as NT$146M – much of which could be mitigated with the use of a perfect ENSO forecast at a total net benefit of US$11.56M.

Econometric models: evaluates relationship and causality between sets of variables. A common application is to use regression models to estimate how changes in certain aspects of environmental and climatological services may affect payoffs, benefits or costs.

- Time series regressions – *time variation*
- Cross sectional regressions – *cross sectional variation*
- Panel regressions – *both time and cross sectional variation*

$$y_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_j x_{ij} + \epsilon_i, \qquad i = 1, \ldots, n$$

Econometric models: evaluates relationship and causality between sets of variables. A common application is to use regression models to estimate how changes in certain aspects of environmental and climatological services may affect payoffs, benefits or costs.

Examples:

- Power utilities usually have own (internal) econometric models that use seasonal forecasts as inputs to predict performance measures.

$$y_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_j x_{ij} + \epsilon_i, \qquad i = 1, \ldots, n$$

Econometric models: applications

- Mirasgedis et al. (2006) use timeseries analysis to estimate medium-term demand for electricity in Greece up to 12 months ahead while controlling for meteorological variance. The inclusion of the meteorological information is found to yield significant gains in forecasting accuracy
- Barthelmie et al. (2008) using data from the UK over 2003-2006, estimate the value of a perfectly accurate demand forecast to be GBP 5.7/MWh.
- As the amount of renewable capacity in power systems increases, the volatility of wholesale price and profit (for generators) is also likely to increase further (Green and Vasilakos 2010). Therefore, reducing forecast error for electricity demand could become even more valuable.

Contingent valuation: survey-based method used to estimate the value of goods for which there is no direct market (and therefore market price cannot be determined). Surveys are used to elicit the willingness to pay for a certain attribute/service/facility.

- CV is based on the assumption that users have a clear understanding of the extra utility that they gain by securing access to the resource that is being valued – they would therefore be willing to bid a price that does not exceed this utility gain.
- Can depict qualitative benefits (e.g. changes in decision-making process).
- Questionnaire designed in such a way so that it elicits the price the respondent is willing to pay for access to the service (or parts of the service).

Contingent valuation: survey-based method used to estimate the value of goods for which there is no direct market (and therefore market price cannot be determined). Surveys are used to elicit the willingness to pay for a certain attribute/service/facility.

- Example: Using seasonal (longer-range) forecasts may enable changes in decision-making process that add quality in areas that extend beyond avoided costs or output variables – for instance, improved productivity, positive spillovers to other management-related areas etc.
- Amegnaglo et al. (2017) use a random survey of 354 maize farmers to find that farmers are willing to pay on average US$5,492 per annum for access to seasonal climate forecasts – which corresponds to US$66.5M at the national level.

Equilibrium models: are designed to consider interactions between different actors/markets in the economy, and use these dynamics to provide an estimate of the overall effect that such interactions are going to have on market behaviour

- Although most of these models follow the same principle of payoff maximisation, unlike decision theory models the actions of a single agent are not viewed in isolation.
- Effect on market outcomes: price, demand and supply
- Partial equilibrium models assume that the effects of such an interaction are confined within a single market.
- General equilibrium models, on the other hand, model the interactions across several markets.

Equilibrium models: applications

Lave (1963) use a decision theory, a partial equilibrium and then a small-scale general equilibrium model to assess the value of better weather information to the raisin industry. They compare the outcome that was generated by a simple decision theory model – where the farmer decides in isolation to the rest of the industry – against the outcome that is generated by a partial equilibrium model in which all farmers get access to the same weather information.

- When the farmer decides in isolation, the model predicts a yearly gain of US$ 90.95 per acre (1960 values), which can be generalised to an industry gain of over US$20M.
- When a partial equilibrium model is used, however, the whole sector is assumed to have access to the same better information, which results in a steep increase in supply and causes profits to fall (at least in the short run).

Game theory: includes a class of mathematical models that are designed to analyse the outcomes of strategic interaction between a set of rational actors (players) who are involved in a situation (game) that has fixed and known rules and potential payoffs.

- Perfect Vs imperfect information games
- One off Vs Repeated games
- Zero sum Vs nonzero sum games

Game theory: applications

Rubas et al. (2008) analyse how payoffs are distributed between countries depending on how early (or late) they adopt ENSO-based climate forecasts. They find that Australian producers enjoy an average increase in surplus of 7.5% and gain the most by using ENSO-based forecasts. US producers' welfare increases on average by 2.2%, while producers in Canada gain 1.3%".

Benefit transfer: used when the value of a particular event is assessed on the basis of the results that were obtained in a separate but comparable study.

Example: a park agency has to decide whether to add a swimming beach to a lake. The decision depends on the value that the beach will add to the park. To use the Benefit Transfer method, they would **first** have to identify existing studies of value that would be comparable to the current project. The **second** step would be about evaluating transferability of the existing values using a set of pre-defined similarity criteria. The **last** step involves implementing these values and making any adjustments to better reflect the values of the project under consideration.

Benefit transfer: applications

- Hallegatte (2012) use the Benefit Transfer method to estimate the economic value of upgrading early warning systems that provide hydro-meteorological information in all developing countries to developed country standards. Their results, based on developed country cost estimates, show that such an upgrade would yield between US$300 million and US$2 billion per year in avoided asset losses due to natural disasters; US$700 million to US$3.5 billion per year worth of human lives saved; and between US$3 and US$30 billion per year of additional economic benefits. The total benefit was estimated within the region of US$3 to US$36 billion USD per year.
- Specifically for seasonal climate forecasts, Benefit Transfer could be applied by using results and lessons learned from weather forecast, but also climate projection, applications.

Choosing between different models

All models have their merits and limitations and the choice of what model to use when depends on the following parameters:

(1) Who is the decision-maker (e.g. single agent model Vs country/community planner)
(2) Data availability – particularly important for econometric models
(3) Optimisation problem and access to information about costs and payoffs
(4) Effect on market outcomes?
(5) Strategic dependency?
(6) Computational complexity.

Choosing between different models

All models have their merits and limitations and the choice of what model to use when depends on the following parameters:

(1) Who is the decision-maker (e.g. single agent model Vs country/community planner)

- Single agent: a company with no influence on market outcomes (no market power), maximising own benefits.

(2) Data availability – particularly important for econometric models

- Timeseries (ARIMA models), access to cost information.

(3) Optimisation problem and access to information about costs and payoffs

- well documented (and mostly accessible) information on costs, decision-trees, internal simulation models

Choosing between different models

All models have their merits and limitations and the choice of what model to use when depends on the following parameters:

(1) Effect on market outcomes?

- None, price-takers.

(2) Strategic dependency?

- Not for a period of time.

(3) Computational complexity.

- Building on existing (company-owned) simulation and regression models.