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Energy, variability and weather finance engineering

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Abstract

Weather derivatives comprise efficient financial tools for managing hydrometeorological *uncertainties* in various markets. With ~46% utilization by the energy industry, weather derivatives are projected to constitute a critical element for dealing with risks of low and medium impacts –contrary to standard insurance contracts that deal with extreme events. In this context, we design and *engineer* -via *Monte Carlo* pricing- a weather derivative for a *remote island* in Greece -powered by an autonomous diesel-fuelled generator- resembling to a standard *call option* contract to test the benefits for both the island's *public administration* and a *bank* -as the transaction's counterparty.

Keywords: Weather derivatives; uncertainty; financial engineering; Monte Carlo; remote island; call option; public administration; bank

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1. Introduction

A major challenge for many *energy systems* in the globe -irrespective of size or composition- is the management of *energy supply uncertainties* that have their grounds on *hydrometeorological* conditions (eg. temperature, rainfall, wind) at the *monetary* level, as most energy units are not sufficiently flexible to adapt to weather condition changes (eg. *wind* turbines are dependent on wind variability with no direct storage capacity; *hydropower* units are primarily dependent on precipitation, with dry periods limiting their output potential continuity; while many types of *thermal*

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plants cannot change rapidly their output in order to meet the real-time demand, etc.). For that reason, *financial risk management* products -called *weather derivatives*- that allow power supply units to protect both their capital and the continuity of their revenues against unpredictable weather conditions -via a mechanism of *financial compensations*- have been developed. In our work we design a *call option* type weather derivative for a simple autonomous energy system in the remote -and non-connected to the continental grid- island of Astypalaia (36^{o}33 N; 26^{o}21 E) in Greece to identify the municipality's benefits across changes in *temperature* and *population* (due to touristic seasonality).

Nomenclature

T_i	*Mean temperature* of day *i*
HDD_i	*Heating Degree Days*; total degrees within a day *i* where the average temperature is *below 18.3* ^{o}*C*
CDD_i	*Cooling Degree Days*; total degrees within a day *i* where the average temperature is *above 18.3* ^{o}*C*
NAD_i	*Net Accumulated Degrees*; after the abstraction of the degree index with the lower value, starting at day *i*
Tick	Monetary value (constant) per NAD_i, expressed in $
OCC	*Option Contract Cost*; the *fee* to buy the option contract, irrespective of whether it yields profit or not
SP	*Strike Price*; the value in units of the weather index (degree days) for which the contract is *triggered*
$Payoff_i$	Difference between NAD_i and the *SP* (in degree days), multiplied with the *Tick*
BE	*Break Even*; the payoff level where the profits cover exactly the *OCC* so that the total position is zero
$Margin_i$	Deviation between the *local* and the *international* oil price due to tourism and temperature, per day *i*
TM_i	*Total Margin*; $Margin_i$ multiplied with the *total number of barrels* of oil equivalent (boe), per day *i*
$Dummy_i$	Component of the $Margin_i$ that concerns population increase due to tourism seasonality
$Actual_i$	*Actual payoff* of a contract on day *i*, based on historical data of *NAD*
$Simulated_i$	*Simulated payoff* of a contract on day *i*, based on the *Monte Carlo* pricing method
TDD_i	*Total Daily Demand* on day *i*; the aggregate daily energy use (in MWh), according to the historical data
PP_i	*Profit Percentage* on day *i*; fraction of monthly TM_i covered by the difference of $Actual_i$ and $Simulated_i$
UAPE	*Unbiased Absolute Percentage Error*; measure for assessing forecast error, *unbiased* with respect to scale
PD_i	*Positive Difference* on day *i*; the difference between $Actual_i$ and $Simulated_i$, only when $Actual_i>Simulated_i$
CDPD	*Contract Days with Positive Difference*; total number of days where $Actual_i>Simulated_i$
TCD	*Total Contract Days*; total number of days for *HDD* or *CDD* contracts (either $Simulated_i\neq 0$ or $Actual_i\neq 0$)
RP	*Risk Probability*; probability of the occurrence of an underpriced contract, i.e. $Actual_i>Simulated_i$
RE	*Risk Exposure*; quantified *loss potential* for the financial institution, expressed in $

1.1. Weather Derivatives: General issues

Weather derivatives are financial tools used by organizations or individuals as part of a risk management strategy to reduce risks associated to a wide range of adverse or unexpected weather conditions. Financial agreements based on the rationale of weather derivatives can be traced in ancient Greece; specifically they are reported to have been profitably used by *Thales of Miletus* (624 – 546 BC) [1]. These financial products are *index-based* instruments that usually utilize observed weather data at a specific weather station to create an index on which an agreed payoff can be based. The main distinction of weather derivatives from *standard insurance contracts* is that the former contracts cover events of low risk, high (occurrence) probability and low financial impact, whereas the latter cover events of high risk, low (occurrence) probability and high financial impact. The *option* is a weather derivative contract, which gives the holder -upon paying an *OCC*- the *right* -however not the *obligation*- to *buy* or *sell* an *underlying* asset at a specific *strike price* by a specific date. The seller has the corresponding obligation to fulfill the transaction -to sell or buy- if the buyer (owner) *exercises* the option. The option is exercised at least at the *BE*, covering exactly the OCC.

1.2. Weather Derivatives: Financial notations

The weather derivative of our analysis is a typical *call option* based on *temperature* –as the underlying index. We use the *HDD* and *CDD* metrics as a measure of our underlying index. Both metrics calculate the difference between