“A decision-making model on hedge transactions in electrical energy commercialization”

1st IAEE Online Conference 2021

Authors: Jonas Pelajo, Naielly Marques, Leonardo Gomes & Luiz Brandão
Institution: Pontifical Catholic University of Rio de Janeiro (PUC-Rio)
E-mail: naielly.lopes@iag.puc-rio.br

Introduction

- Agents of the electricity sector at times can find themselves in a short position in the market.
- **Reasons:**
  - Deficit in power generation – in the case of a hydroelectric generator
  - Uncertainty in wind speed – in the case of a wind generator
  - Speculative reasons – in the case of a trader
  - Delays in the construction of a new power plant
  - Others

Introduction

- **Consequence:**
  - The electricity generation may be insufficient to comply with the energy sales contract.
  - The agents are obligated to purchase their energy shortfall in the spot market to fulfill their sales contract commitments, which exposes them to price risk.

- **Solution:**
  - Firms can hedge this risk by entering into forward contracts in which the exposed agent can contract part or all of their position at a pre-established price.

Introduction

- **Objective:**
  - Analyze the decision making on the hedge operation, aiming to maximize the agent's profits subject to a certain level of risk protection.

- **Contribution:**
  - Develop a decision support tool to determine how much an agent should hire from his short position based on his willingness to pay the risk premium and the hedge transaction.

Model

- We adopt the preference function developed by Luz (2016), which allows modeling the variation of the risk aversion level of an agent for different preference ranges.

$$ECP\_G = E\left[U\left(X\right)\right] = \lambda_0 E\left[X\right] + \sum_{n=1}^{N} \lambda_n CVaR_{\alpha_n}\left(X\right)$$

where *ECP_G* is the extended preference function of *CVaR* generalized, *X* is the financial position, α is the confidence level and λ is the measure of investor risk aversion, where $\lambda_i \geq 0$ e $\sum_i \lambda_i = 1,\ i \in [0, N]$

Model

- Considering that the agents are in a short position in the electricity market, the financial position *X* can be expressed by:

$$X = \sum_{t=1}^{\tau} \left[\left(-\left(1-\delta\right)\pi_t - \delta\phi_t + \chi \right) \upsilon_t \eta_t \right]$$

where δ represents the percentage of the purchase decision of the hedge transaction; π_t is the spot energy price (R$/MWh); ϕ_t is the future price estimated by the forward energy price curve (R$/MWh); χ is the opportunity cost (R$/MWh); υ_t is the uncontracted amount (MW); and η_t is the number of hours in month *t*.

Model

- From the utility function developed by Luz (2016), we can define the Certainty Equivalent (φ) and the Risk Premium (γ).

$$\varphi = U^{-1}\left(E\left[U\left(X\right)\right]\right) = U^{-1}(\lambda_0 E\left[X\right] + \sum_{n=1}^{N} \lambda_n CVaR_{\alpha_n}\left(X\right))$$

$$\gamma = E\left[X\right] - \varphi$$

- The Certainty Equivalent reflects the situation of the agent's indifference between hedging and being exposed to the energy price risk.
- The Risk Premium is the difference between the average of the financial position *X* and the Certainty Equivalent, which represents the premium required by the hedge transaction.

Model Parametrization

- Determine the limit of change in the level of risk aversion of the investor and its degree of risk aversion in each range of results in relation to the others.
- As it is a relative aversion, it is recommended to use parity comparison methods to define the function parameters.
- The AHP is based on the decomposition and synthesis of the peer-to-peer relationships between the criteria, where it is sought to prioritize the alternatives through a single measure of performance (Saaty, 1991).
- This method is flexible, simple, easy intuition for the decision maker and allows the hierarchy of the criteria according to their assigned attributes.

Model Parametrization

- To apply this method it is recommended:
  - **Step 1**: Definition of the problem, objectives, existing alternatives, decision-making criteria and selection of the decision makers.
  - **Step 2**: Decision makers ponder the importance of each of the criteria in relation to another, forming a matrix of judgments.
  - **Step 3**: Perform the normalization of the judgments to obtain a matrix of weights attributed to the parity comparisons (matrix of preferences) and to each of the criteria defined in the first step.

Model Parametrization

- To evaluate the robustness of the model, Saaty (1991) proposed the following indices:

$$CI = \frac{\lambda_{max} - n}{n-1} \qquad CR = \frac{CI}{RI(n)}$$

If $CR \leq 10\%$ the parity comparison matrix has acceptable consistency and the weights are valid and can be used (Saaty, 1991).

where: λ_{max} is the major eigenvalue of the judgment matrix, *n* is the order of the judgment matrix and *RI(n)* the random consistency index for matrices of order *n*, which approximate the results found by Saaty (1991):

n	3	4	5	6	7	8	9	10
$RI(n)$	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Source: Saaty (1991).

Numerical Application

- We consider the case of a major agent in the Brazilian electricity sector that needs to make its hedge decision for the second half of this year.
- We assume that this decision can be made in two different ways:
  - Make the hedge decision in July to cover the agent's exposure through September and make another hedge decision in October to cover the agent's exposure through the end of the year; or
  - Make the hedge decision in July to cover the agent's exposure throughout the second half of the year.
- The objective is to define the optimal hedge level that maximizes the agent's profits conditioned to a certain level of risk protection in each of these blocks (July to September; October to December; and, July to December).

Numerical Application

- First, we consider a fixed opportunity cost equal to 201.00 (R$/MWh) and the following values:

Month	υ	ϕ	η
July	-35.44	325.00	744
August	-61.30	325.00	744
September	-66.51	325.00	720
October	-92.54	310.00	744
November	-75.90	310.00	720
December	-59.32	310.00	744

- Note: υ is the uncontracted amount (MW); ϕ is the forward price (R$/MWh); and η is the number of hours.

Numerical Application

- The proxy for energy price in the spot market is assumed to be the PLD.
- We use the monthly simulation made by ONS (National System Operator) for the year 2021 for the Southeastern and Midwestern Brazilian energy market.

Blocks	Start	End	$\bar{\pi}$	$\bar{\upsilon}$
1	July	September	350.05	-54.29
2	October	December	230.72	-75.92
3	July	December	290.39	-65.10

- Note: $\bar{\pi}$ represents the average spot energy price in each block (R$/MWh) and $\bar{\upsilon}$ is the weighted average of the uncontracted amount in each block (MW average).

Numerical Application

- We establish two target levels in this model: one representing the intermediate risk and the other the extreme risk.
- We assume that the intermediate risk is the expected outcome of the worst 30% scenarios and the extreme risk, the worst 5%.
- We obtain the following values, which will be replaced in the ECP_G function:

$$N = 3;\ \alpha_1 = 70\% \text{ or } F\left(0\right);\ \text{and } \alpha_2 = 95\% \text{ or } F\left(P_{\max}\right)$$

Numerical Application

- The intermediate and extreme risks and the expected value of the results are considered the criteria to be compared and prioritized.

- We use the AHP method with 9-point Saaty scale. The following table presents the judgment matrix.

	Extreme Risk	Intermediate Risk	Expected Value
Extreme Risk	1.00	1.50	3.00
Intermediate Risk	0.67	1.00	1.50
Expected Value	0.33	0.67	1.00
Total	**2.00**	**3.17**	**5.50**

- The values adopted in this matrix were defined by the team responsible for the hedge decisions of this major agent that we are analyzing based on their experiences in the energy sector.

Numerical Application

- The weights matrix is calculated from the division of each value defined in the matrix of judgments by the sum found in each column.

	Extreme Risk	Intermediate Risk	Expected Value
Extreme Risk	0.50	0.47	0.55
Intermediate Risk	0.33	0.32	0.27
Expected Value	0.17	0.21	0.18

- Criterion weight values are defined as the mean of each line of the weight matrix, while the consistency values are calculated from the multiplication of the judgment matrix by the criterion weight values.

	Criterion Weight	Consistency
Extreme Risk	0.51	3.01
Intermediate Risk	0.31	3.01
Expected Value	0.19	3.01

Numerical Application

- After that, we calculated the CI = 0.0046 and the CR = 0.79% of this model.
- Note that the CR is less than 10%, demonstrating the robustness of the model.
- The next table presents the values considered for the probability as well as the values found for the probabilistic weight.

	Probability	Probabilistic Weight
Extreme Risk	0.05	0.04
Intermediate Risk	0.30	0.22
Expected Value	1.00	0.74

Numerical Application

- Finally, we prioritize the importance of the criteria from the multiplication of the criterion weight by the probabilistic weight. Note that by dividing each of these values by the sum of them, we can determine the parameters of the ECP_G function:

$$\lambda_0 = 61.33\%,\ \lambda_1 = 30.34\% \text{ and } \lambda_2 = 8.33\%$$

- Considering this, we optimize the financial position equation in order to estimate the percentage of the purchase decision of the hedge transaction in each of the blocks under analysis.

- Then, we calculate the Certainty Equivalent, the Risk Premium and the value that the agent is willing to pay for the hedge in each of the blocks.

Results

Blocks	δ (%)	Mean (R$x1000)	$CVaR_{70\%}$ (R$x1000)	$CVaR_{95\%}$ (R$x1000)	φ (R$x1000)	γ (R$/MWh)	ω (R$/MWh)
1	100.00%	-14,863.05	-14,863.05	-14,863.05	-14,863.05	0.00	350.05
2	0.00%	-6,434.55	-37,308.86	-58,620.64	-19,022.13	75.09	305.82
3	45.30%	-27,844.56	-55,185.49	-71,285.66	-37,788.63	34.59	324.98

Conclusion

- If the agent choose to make the hedge decision in two stages, he should contract 100.00% of the uncontracted amount in the 3rd quarter (54.29 MW average) and not hedge in the 4th quarter.
- However, if the agent choose to make the hedge decision in July to cover its exposure throughout the entire second half of the year, the model suggests the purchase of 45.30% of its position.
- This means that the optimal decision in this case is to buy 29.49 MW average (45.30% of the uncontracted amount in the 2nd semester) for up to 325.00 R$/MWh.

Contribution & Limitation

- **Main contribution:**
  - The proposed decision support tool allows agents that are in a short position in the electricity market make an optimal decision on hedge transactions.

- **Limitation:**
  - Although the model is robust, its main limitation derives from the difficulty in determining the parameters of the preference function. Further studies on the parameterization of this preference function are recommended.

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