# Prediction Markets as Forecasting and Hedging Instruments within the Renewable Electricity Sector

IEA Task 51, UCD Dublin, September 13th 2022

*Dr. Paul Cuffe & Ms. Mahdieh Shamsi*
*University College Dublin (UCD)*

This research has been funded by the Sustainable Energy Authority of Ireland under the SEAI Research, Development & Demonstration Funding Programme 2018, grant number 18/RDD/373, and additional funding provided by the UCD Energy Institute.

# Decentralised Forecasting Methods in Energy Sector

**Crowdsourcing** methods to gather data from various sources

What is the **motivation** to provide accurate data?

In **prediction markets:** tangible **monetary incentives** for participants

# Prediction Markets

- Participants bet on the outcome of **future events** and trade contracts whose **payoffs** depend on the **true outcome** of the event

- Will candidate A be elected as president?
  **Binary : Yes / No : Winner-takes-all**

- **1 $ per share** for correct answers and nothing to others

- **Market price** represents the **probability** of the outcome

# Blockchain-hosted Prediction Markets

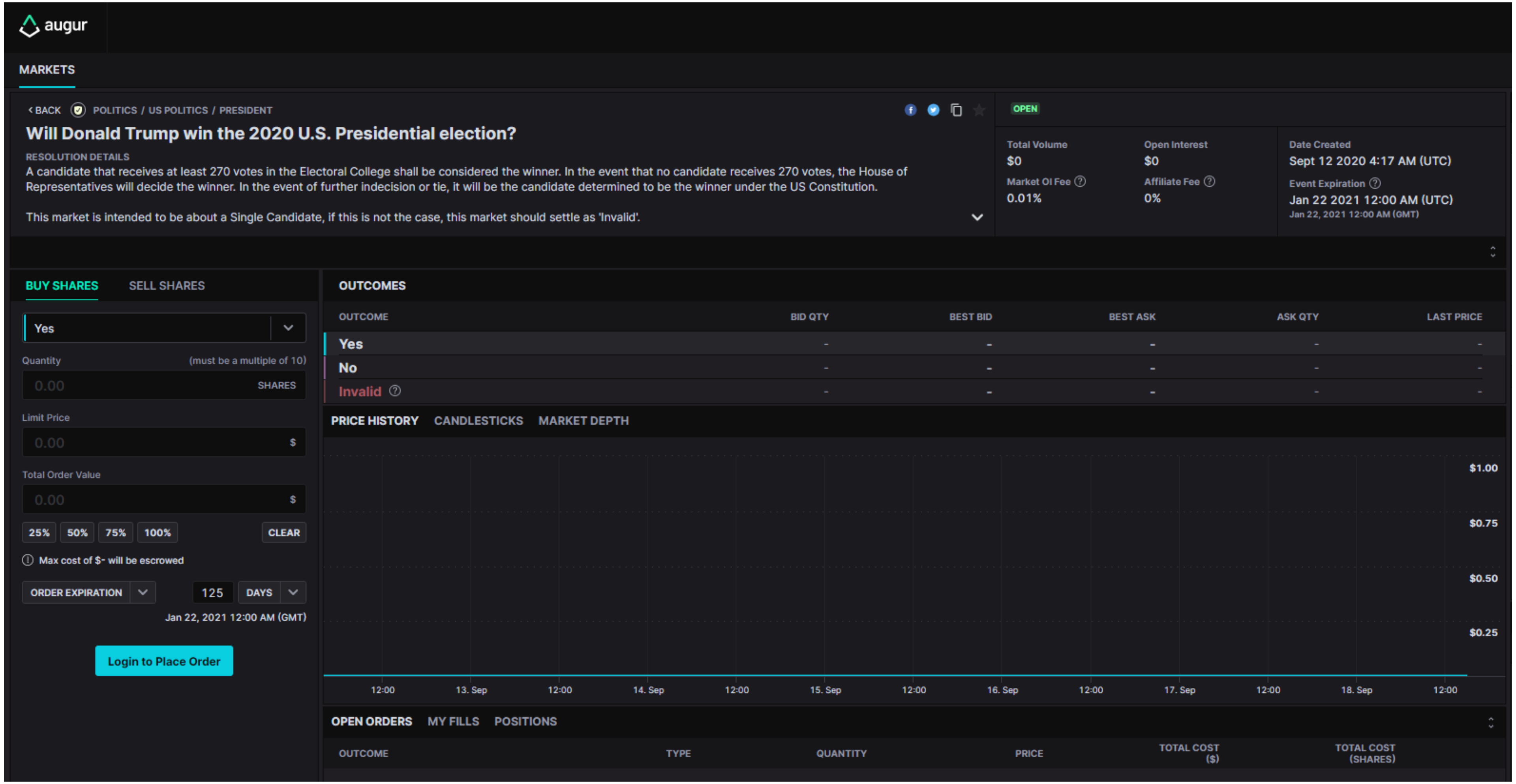
- In **Centralised** platforms, a **trusted entity** performs market clearing tasks
- **Blockchain** provides a **decentralised** data ledger for recording and validating transactions **trustlessly**
- The medium of exchange: **cryptocurrencies**
- Available platforms: Gnosis, Stox, Hivemind and **Augur**

# Example of Augur platform

Buy or Sell

Quantity

Limit Price



# Prediction Markets for Probabilistic Forecasting of Renewable Energy Sources

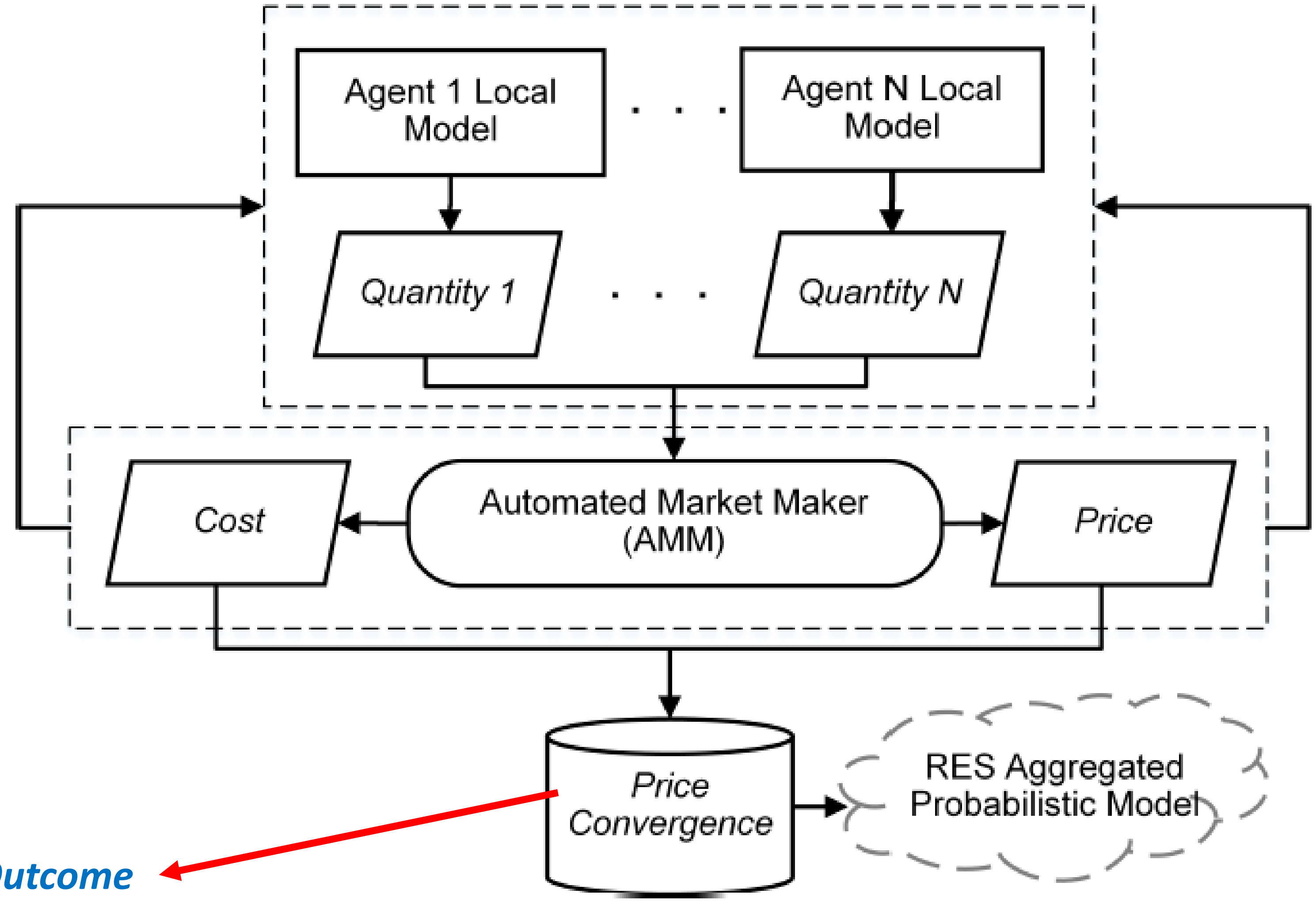
Mahdieh Shamsi, *Graduate Student Member, IEEE*, and Paul Cuffe, *Member, IEEE*

***Abstract*—This paper demonstrates how a binary prediction market is capable of achieving a probabilistic renewable energy forecast. In prediction markets, participants trade shares associated with the outcome of unknown future events (here, the renewable production, as a random variable), and the instantaneous price of shares represents the probability of the outcome. The focus of this study is to exploit this informational value of the prediction market price in renewable energy forecasting. To this end, in this paper three different methods of renewable probabilistic forecasting have been considered as the trading agents in a binary prediction market, the aggregated probability of the renewable output is elicited from the equilibrium price in this market and finally, the full cumulative distribution function of possible renewable output is extracted through regression analysis. The proposed method is applied to the test cases of three onshore wind farms in Australia. The simulation results suggest that the performance of the proposed method is superior to the individual models and forecasting is improved in**

Decision making problems, mentioned above, can be improved by taking into account the uncertainty information of the point forecasts through probabilistic forecasting. Extensive research exists on this topic in the literature, for a detailed classification and review, we refer to [8], [9] and [10]. Here, within the scope of this paper, it suffices to note that these methods can be categorised into two groups: parametric methods assume a pre-defined shape for the distribution of forecast errors, such as Gaussian or beta ([11] and [12]) and estimate the relevant parameters, while nonparametric methods obtain empirical probability distributions from the historical data ([13] and [14]) without any prior assumption on the shape of errors distribution.

The above mentioned forecasting methods can be improved

# Probabilistic Forecasting of the Renewables' Output




*Probability of the Outcome*

# AMM with Logarithmic Market Scoring Rule (LMSR)

*Cost Function:*
*Gives total cost of order*

$$C(b, \pi_c, q) = b \ln(\pi_c(\exp(q/b) - 1) + 1)$$

*Price Function:*
*Updates market price after filling order*

$$\pi_r(b, \pi_c, q) = 1/(1 + \frac{1/\pi_c - 1}{\exp(q/b)})$$

*Liquidity parameter*

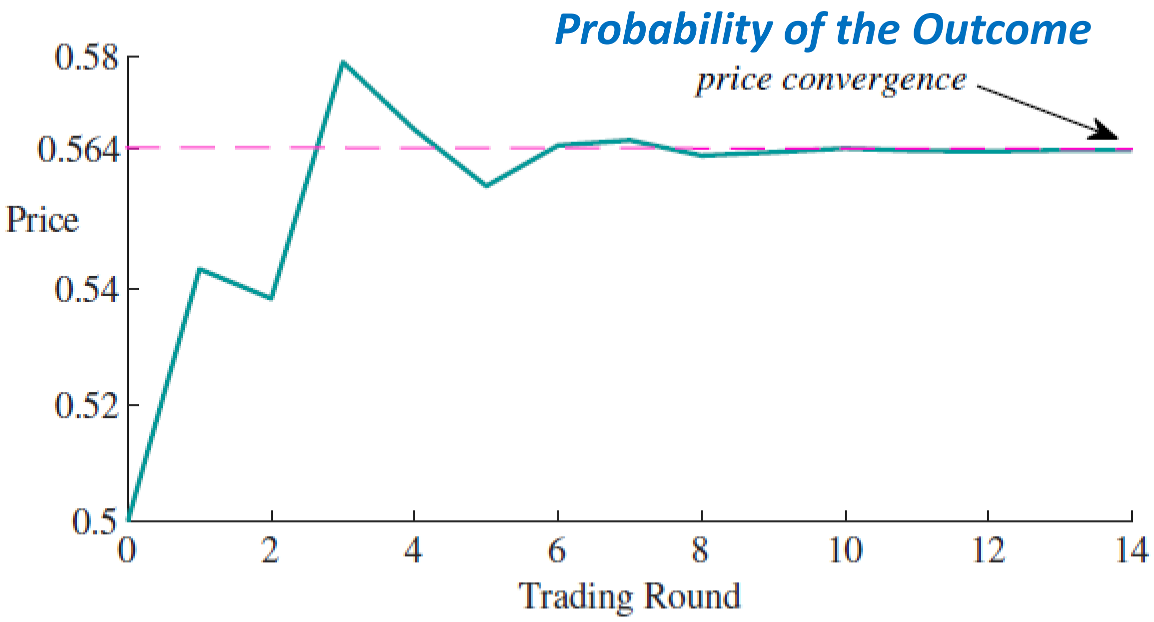
*Current market price*

*Quantity of shares*

*Agents' Trading Problem:*
*Max*

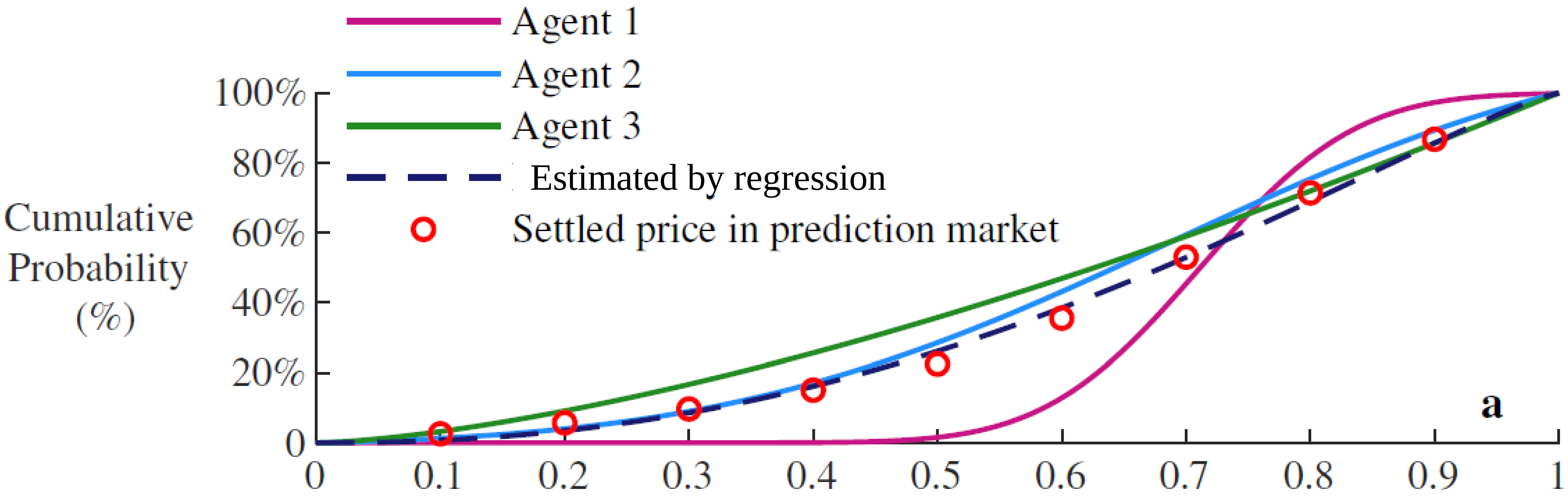
$$p_j U_j(q_j - C(b, \pi_c, q_j)) + (1 - p_j) U_j(-C(b, \pi_c, q_j))$$

# Sample of a binary market simulation




Will the renewable generation be less than a certain MW amount?

# Estimating the Full Predictive Density



# A Prediction Market Trading Strategy to Hedge Financial Risks of Wind Power Producers in Electricity Markets

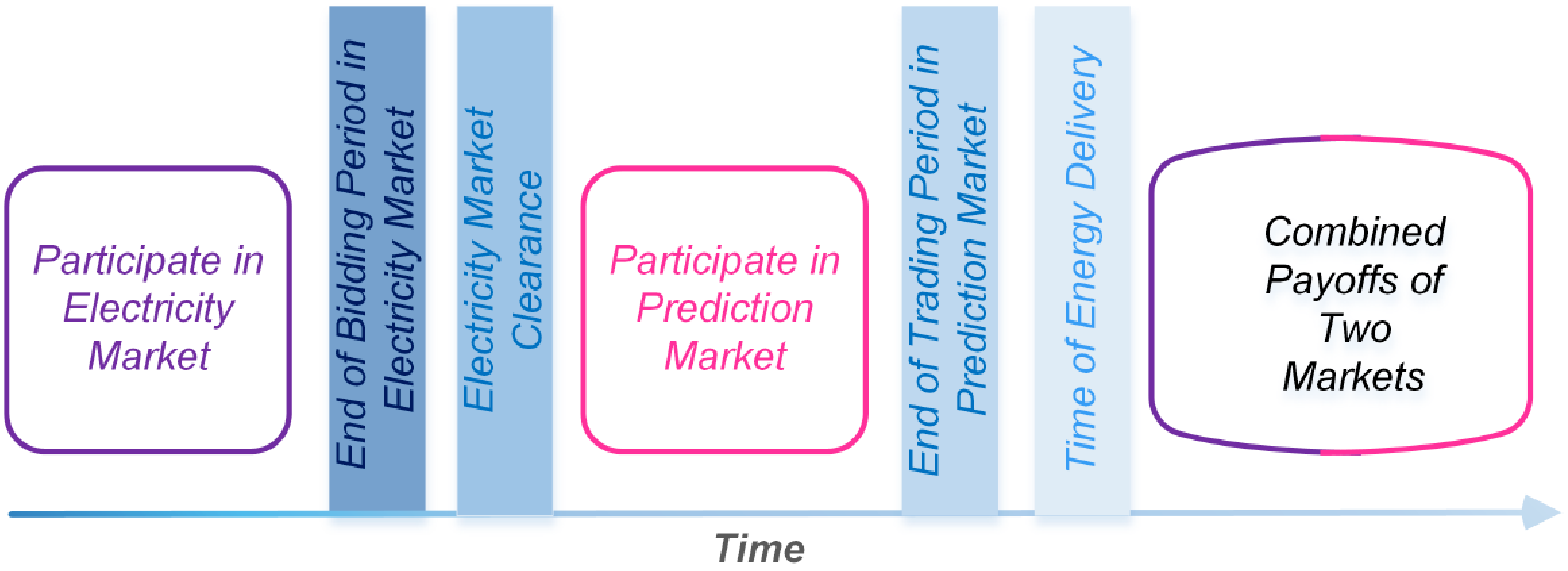
Mahdieh Shamsi, *Student Member, IEEE*, and Paul Cuffe, *Member, IEEE*

***Abstract*—Wind power producers participating in day-ahead electricity markets are compelled to pay imbalance costs if they do not generate the same amount of power as they had bid for. These imbalance costs comprise a significant proportion of their income. To reduce the risk of such financial losses, this paper employs the idea of trading in a separate *prediction market*, as a hedging method. In prediction markets, participants trade shares associated with a certain outcome of an event. We propose that the wind power producers might participate in a prediction market to trade the future value of the wind power and by taking an opposite position in comparison to the electricity market, the imbalance costs will be offset through payouts in the prediction market. Wind power is modelled as a stochastic variable and an optimal trading strategy is developed where the trading volume in the prediction market is**

| | |
|---|---|
| $F_P(p)$ | cumulative distribution function of $p$ |
| $f_P(p)$ | probability distribution function of $p$ |
| $G(x)$ | payoff function of each long share in a prediction market (\$) |
| $G^n(p)$ | net payoff of $n$ long shares in the wind power prediction market (\$) |
| $H(x)$ | payoff function of each short share in a prediction market (\$) |
| $H^n(p)$ | net payoff of $n$ short shares in the wind power prediction market (\$) |
| $j$ | revenue of the wind power producer (\$) |
| $k$ | settlement fees in the prediction market (%) |

# Hedging the Renewables' Revenue in the Day-ahead Electricity Market

Taking opposite positions in the two markets:



# Electricity Market

- **Day-ahead** electricity market, **balancing market**
- **Deviation** between submitted bids and actual generation: **Imbalance Costs**
- Resource volatility of **renewables**
- Financial Risk to be **hedged**

# Imbalance cost (deviation loss)

$$L_e(p) = \begin{cases} P_{max}\, q\,(p - c^*) & p \leq c^* \\ P_{max}\, \lambda\,(p - c^*) & p \geq c^* \end{cases}$$

*Underproduction*

*Overproduction*

Dual Settlement mechanism

*Imbalance prices*

*Actual generation of renewable (stochastic variable)*

*Day - ahead Bid*

# Scalar Prediction Market

*Short shares payoff*

$$H(x) = \begin{cases} 1-k & x \le x_1; \\ (x_2 - x)(1-k)/(x_2 - x_1) & x_1 \le x \le x_2; \\ 0 & x \ge x_2. \end{cases}$$

*Long shares payoff*

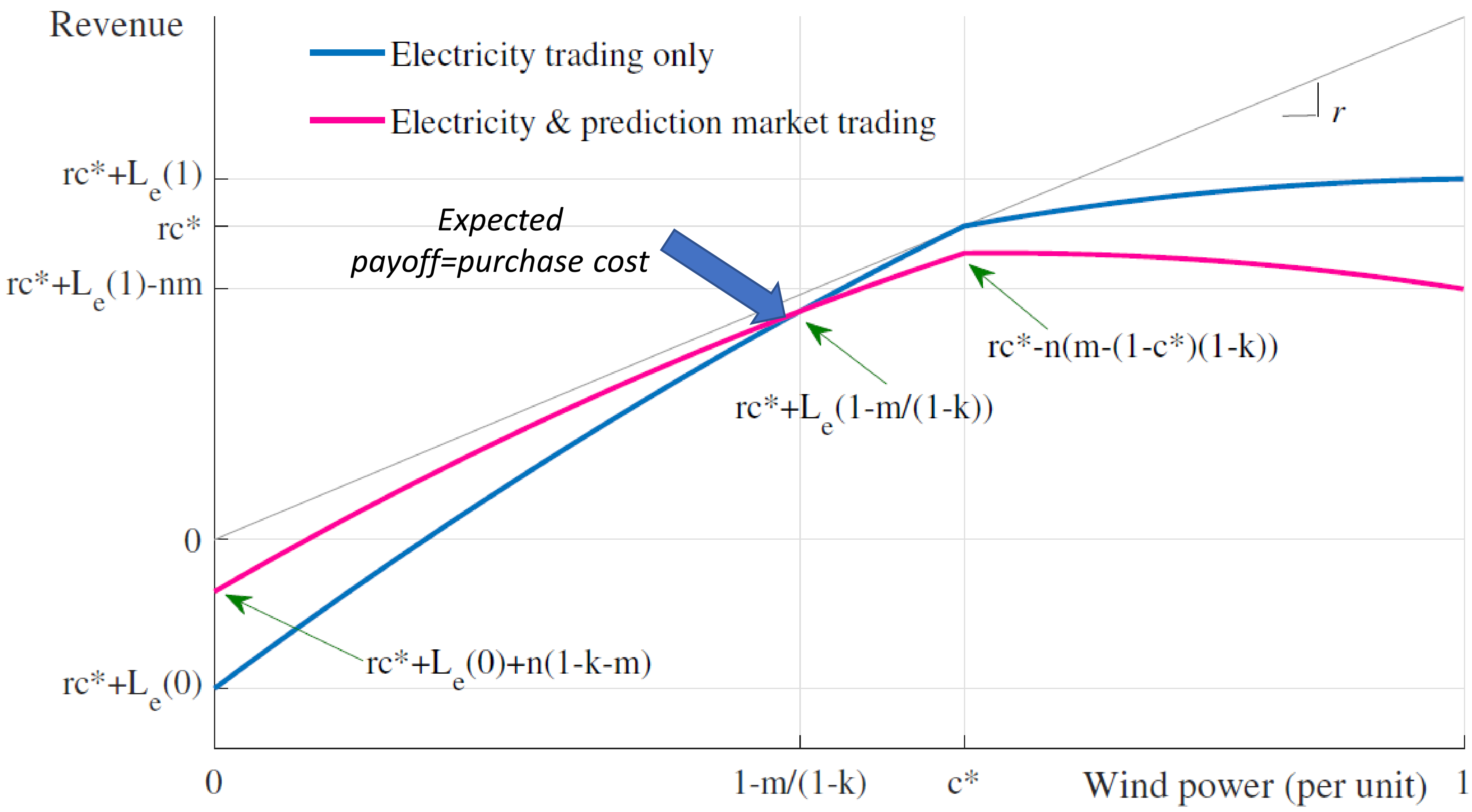
$$G(x) = \begin{cases} 0 & x \le x_1; \\ (x - x_1)(1-k)/(x_2 - x_1) & x_1 \le x \le x_2; \\ 1-k & x \ge x_2. \end{cases}$$

*Actual value of the variable*
*Here: p (renewable generation)*

*Upper band*

*Lower band*

# Combining revenues of the two markets



# Conclusion

**Prediction markets** benefit:

- Renewable energy **producers**
- Power system **operators**

BY:

- Providing an **accurate forecasting signal**
- **Hedging revenue** against imbalance costs in electricity market

# Outlook and Future Works

- **Coordinated bidding** strategy in the day-ahead electricity market and the prediction market in the **hedging application** area

- The **forecasting application** area can be extended by considering the agents' **learning opportunity from the prediction market settled price** (in the previous trading round) to readjust their beliefs (subjective probabilities)

UCD ENERGY INSTITUTE

# Thank you

# Questions?

paul.cuffe@ucd.ie or mahdieh.shamsi@ucdconnect.ie