Energy Analytics

Lecture 6: Hedging Strategies

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In this lecture:

- Using of copulas in risk modelling.
- Different types of financial contract used to hedge risk
- Combining contracts for differences for gas and electricity

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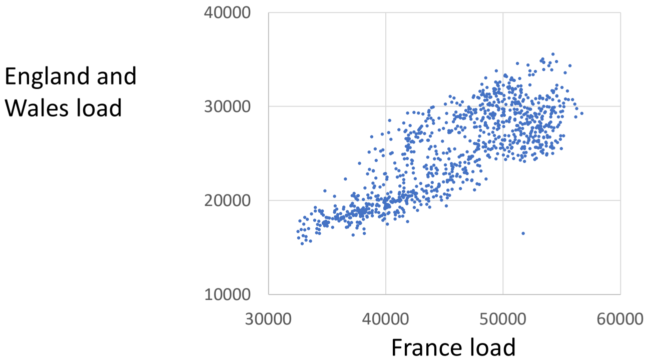
Beyond the scatter plot

- A good option to describe the behaviour of two variables is to use a scatter plot



- Copulas look at this after factoring out the two individual distributions

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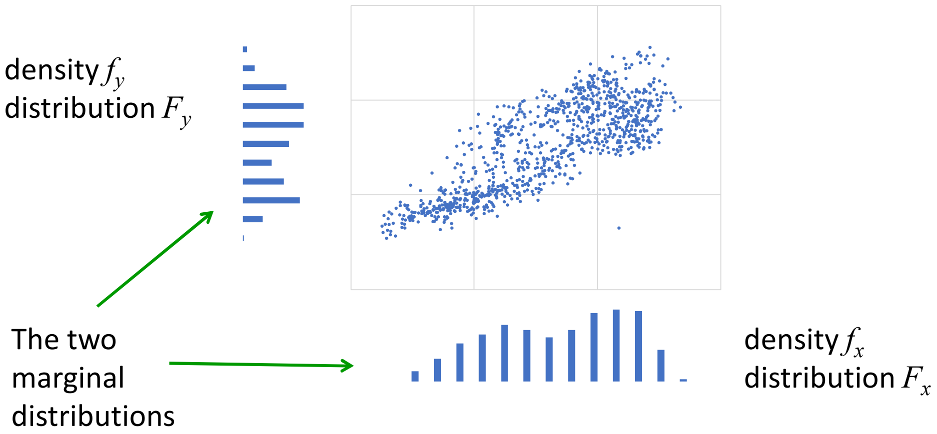
Fundamentals of copulas



How do we represent the additional information apart from the marginals?

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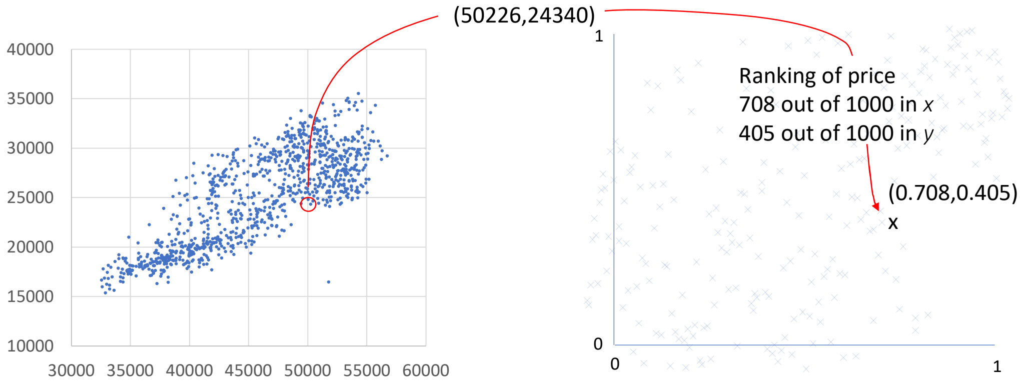
The copula transformation

- Map a point (a, b) to the estimated value of $\left(F_x(a), F_y(b)\right)$ made by looking at the rank ordering. The highest x value gets mapped to 1, the lowest to zero, and similarly with y values



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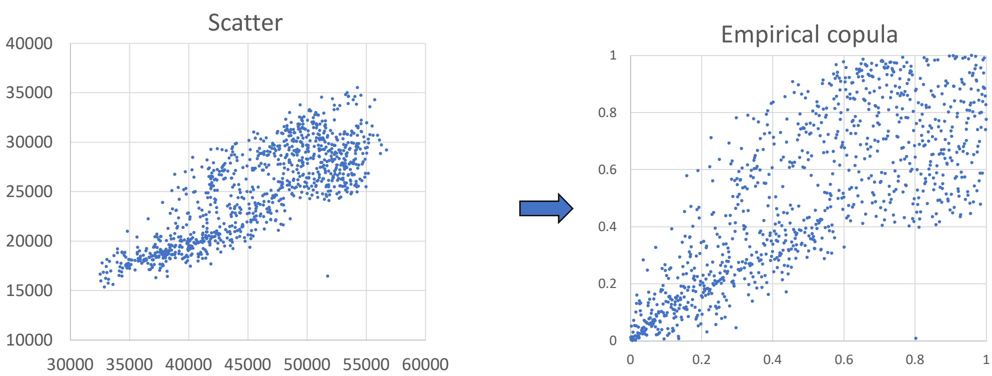
The empirical copula

- Mapping each point in the data to its corresponding $(F_x(a), F_y(b))$ position generates the empirical copula plot.
- Equivalent to stretching and squeezing the axes so that the marginal distributions become uniform.



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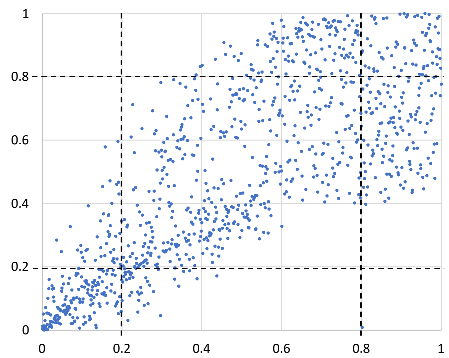
Is correlation the same for high and low values?

- The empirical copula plot is a good way to look at the structure of correlation. How does correlation between high values compare with correlation between low values?



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The copula density

- We end up with a (copula) density over the unit square [0,1] x [0,1]
- The copula plot represents a sampling from this density
- The copula density has to satisfy various conditions, most important is that the integral over any horizontal or vertical line is 1
- If the variables are independent then the copula density is uniform over the square

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Differences between futures and forwards

- Futures contracts are highly standardized, but the terms of a forward contract can be privately negotiated.
- Futures are traded on an exchange, but forwards are traded over-the-counter (OTC).
- To eliminate counterparty risk, in a futures contract, the exchange clearing house itself acts as the counterparty to both parties in the contract.
- Also futures positions are marked-to-market daily, with “margins” required to be made available by participants. When the price of the futures contract changes participants have to provide the money required to settle.
- Forwards are only settled at the time of delivery, so the profit or loss on a forward contract is only realized at the time of settlement.

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Contracts for differences

- A contract for differences is an agreement between two parties and relates to a price in the future.
- Usually an average price. For example we could agree a CFD based on the average price over the peak period (8am to 8 pm) for the three months starting January 2025.
- A CFD has a strike price f (in \$) and a quantity Q (in MWh).
- For example if company A buys a CFD with strike price $f = \$40$ and quantity $Q = 100$ from company B and the actual average price over the relevant period is $p = \$45$ per MWh, then the seller B pays to the buyer A an amount $Q(p - f) = \$500$.
- In the event that the actual average price is lower than the strike price then the buyer pays the seller the difference.

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Reduced risk for a retail supplier

- A retailer has to supply at a fixed retail price r but buys at a varying wholesale price p. The retailer is at risk if the wholesale price peaks.
- Consider a retailer **buying** a CFD for the quantity Q_C that they expect to sell to consumers, with a strike price at the forecast average price.
- Profit if actual amount sold is Q will be

$$\underbrace{Q(r-p)}_{\text{Profit/loss from sales}} + \underbrace{Q_C(p-f)}_{\text{Profit/loss from CFD}}$$

- When $Q = Q_C$ then profit is fixed at $Q(r-f)$ which is the forecast profit
- Retailer remains at risk if demand is higher than Q_C and price peaks (when the CFD will not be enough to compensate for the loss from sales)

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Reduced risk for a generator

- A generator is the natural counterparty to the retail supplier.
- Consider a generator **selling** a quantity Q_C of CFDs at a strike price equal to the forecast price.
- This effectively guarantees that strike price for an amount Q_C of its output
- If c is the cost of power generation, then profit if actual amount sold is Q will be

$$\underbrace{Q(p-c)}_{\text{Profit/loss from sales}} + \underbrace{Q_C(f-p)}_{\text{Profit/loss from CFD}} \qquad \boxed{= Q(f-c) \quad \text{if } Q = Q_C}$$

- The generator is at risk if the amount sold is less than Q_C and the price peaks (this is likely when the generator breaks down)

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CFDs for renewables in the UK

- The UK has set up the Low Carbon Contracts Company (or LCCC) to act as counterparty for renewable generators who want to build capacity and get a guaranteed price.
- Auctions take place in which generators bid a strike price for a 15-year period. The lowest strike prices are accepted.
- Generators are sellers and are paid the difference between the strike price (indexed to a given year) and the reference price (calculated as an average market price for GB) for the quantity that they actually generate.
- In the most recent CFD round (Sept 2019) accepted strike prices were around £40 per MWh for offshore North Sea wind power indexed to 2012 prices.

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Other (financial) derivatives

- A **call option** gives the right (but not the obligation) to buy an underlying financial instrument at some point in the future at a given 'strike' or 'exercise' price.
- If the date of the exercise of the option is fixed it is a European option, if the option can be exercised at any time before the expiry date it is an American option.
- A **put option** is similar: it gives the right (but not the obligation) to sell the underlying stock at a given price.
- Trade takes place for a small set of different exercise dates, and a set of different strike prices.
- Can look at natural gas options at the Henry Hub price. Data from Chicago mercantile exchange (prices in $ per Millions BTu = 10 therm =293 kWh): www.cmegroup.com/trading/energy/#naturalGas

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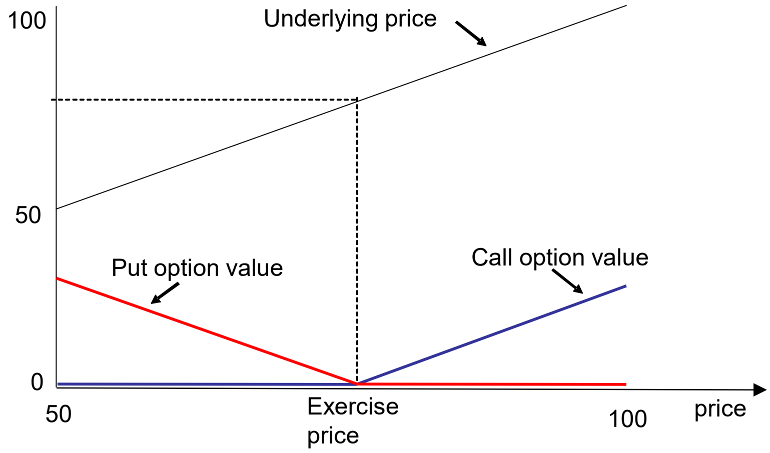
Value of options we hold



- Value of put and call options depends on what happens to the underlying price.
- If we have sold the options then these amounts are what we have to pay, and the value is the negative of this.

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More on financial options

- Options are bought and sold independent of any holding of the underlying commodity or financial instrument.
- A company may have a portfolio of options.
- Company A thinks gas prices will not move very far. They sell a put option at an exercise price of $24 and also sell a call option at a high price of $30.
- Company B is risk averse and imports LNG. They buy put options at an exercise price of $25 to provide insurance against a drop in price. They also sells a call option at a high exercise price of $29. This limits the possibility of a large gain, but the money received for the call option can be put towards the cost of buying the put option.

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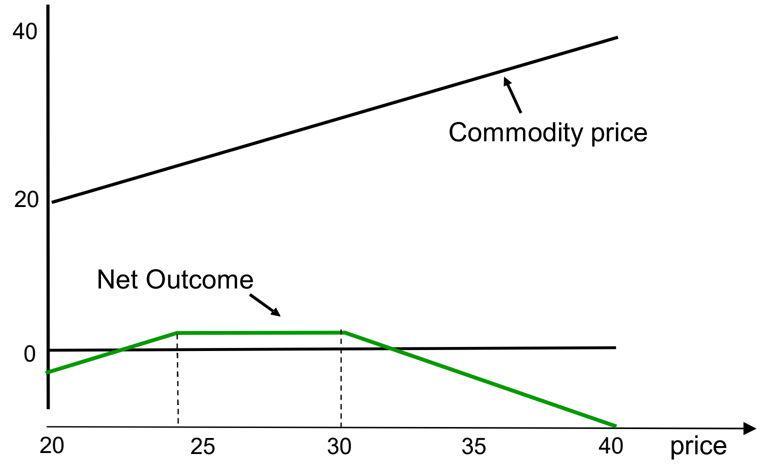
Portfolio of options

- Company A, sells a put option at an exercise price of $24 and sells a call option at an exercise price of $30.



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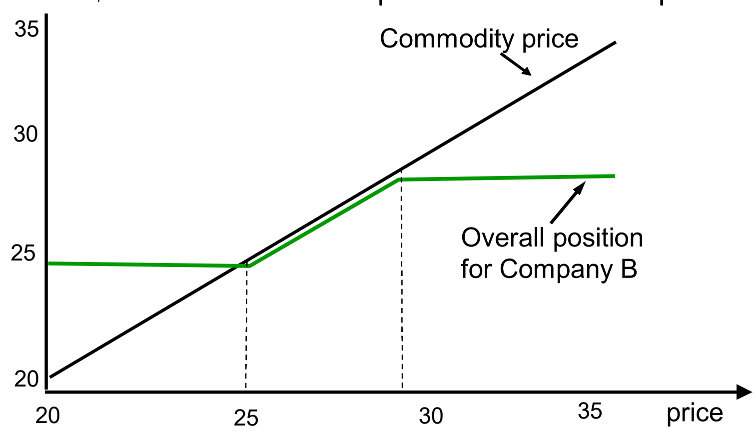
Portfolio of options

- Company B imports gas, and wants to limit downside risk (paying a fixed price but being able to sell only at a lower price). It buys a put option at an exercise price of $25 and sells a call option at an exercise price of $29.



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Other derivatives in electricity markets

- We could expect to see put and call options for electricity futures being traded.
- In Australia $300 caps are traded. But in many markets these type of option contracts either do not exist or are not actively traded.
- More broadly the volume of trades in electricity derivatives are not as high as for other commodities.
- This is partly because the contract markets are dominated by participants in the wholesale market, who by their bids in the wholesale market can influence the spot price. This makes it difficult for other traders (banks/ speculators etc) who have less information .

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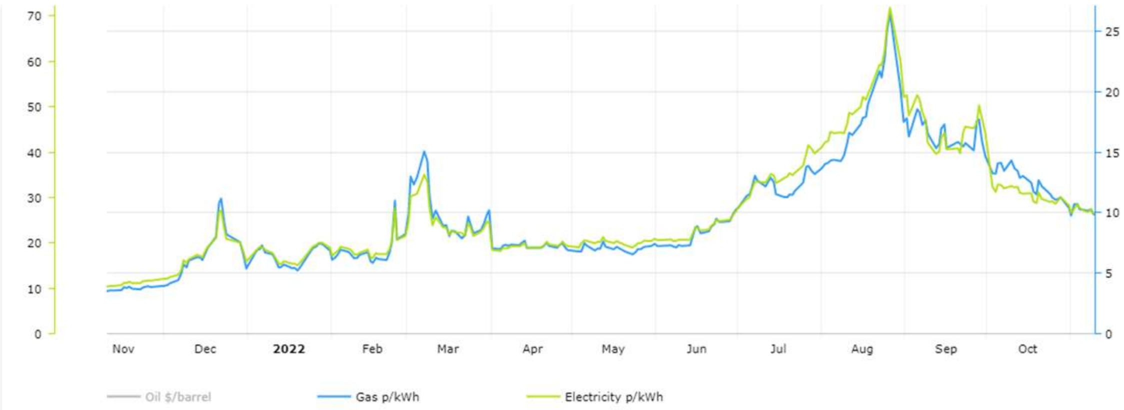
Gas often sets price

- Since majority of prices are set by gas generators who have a varying cost of fuel we find a close connection between gas and electricity prices



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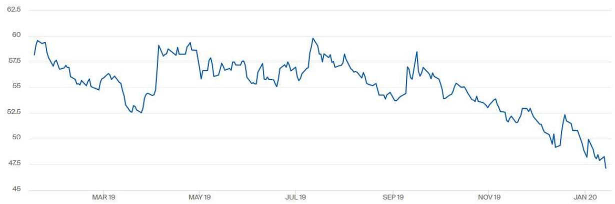
Same relationship in futures

- Can look at ICE prices for Dec 20 contract

Electricity Base load £/MWh



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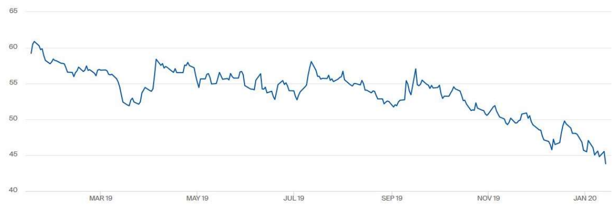
Gas pence per therm



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Risk premium for electricity

- Since futures lock in a price we may ask whether there is a consistent extra cost. A retail supplier would be willing to pay more than the average price for certainty.
- But a generator has opposite incentives – and would agree to receive less for certainty.
- In practice it often appears that the futures price is higher than the spot (called "contango" by traders)
- More important for retailers to hedge than generators.
- But the average price is significantly influenced by rare events, so it is hard to be sure of the size (or direction) of the risk premium.

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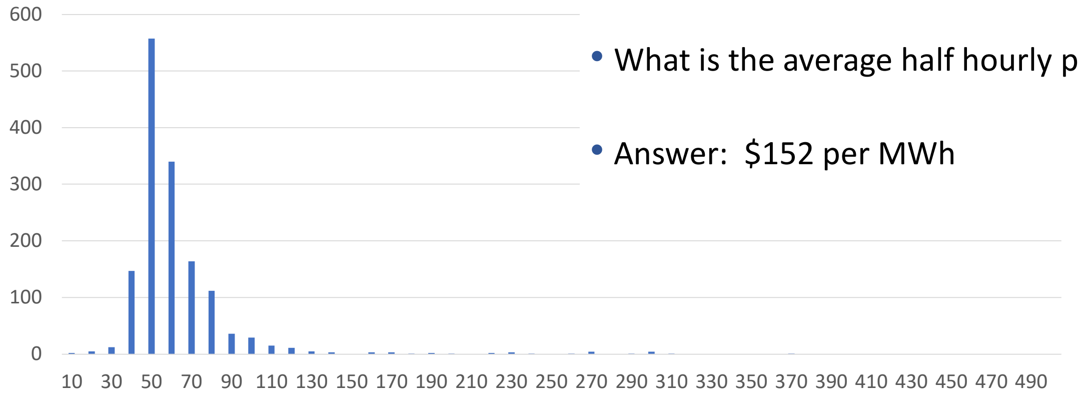
An example: 30 minute prices in NSW Australia

- Histogram of prices for January 2020.
- What is the average half hourly price ?
- Answer: $152 per MWh



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Load and price time series

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Risk and hedging assignment

- Drango is a 700 MW generator using CCGT technology, made up from two 350 MW units.
- Drango generates only in the peak period of 8 am to 8 pm
- Drango has conversion efficiency of 50%, with a therm of gas producing 14.52 kWh of energy. When operating normally Drango consumes 48223 therms per hour.
- Drango has an existing contract for gas supply at 50 pence per therm for an average of of 250,000 therms per day. Additional gas required will be purchased at the market price.
- In addition to fuel costs, the plant costs £140,000 per day to run in operating and financing costs.

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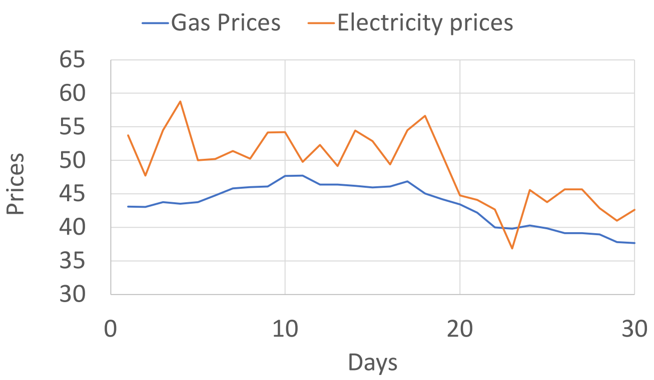
Price history

- We assume that prices look like they did over the same period in 2019



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Tasks

1. Estimate the average daily profit over the 30-day period.
2. Generate a simulation of gas and electricity prices assuming a bivariate normal distribution with the same means, and covariances as the data from November 2019 and estimate the 95% expected shortfall for daily profit.
3. Each day there is a 4% chance of an outage in which one of the generation units is unavailable. On these days the plant running costs are the same as before, generation is reduced to 350 MW and fuel consumption is correspondingly halved. Estimate the 95% expected shortfall for daily profit.
4. The current prices for a futures contract (CFD) are £49 per MWh for peak period electricity, and 43.5 pence per therm for gas. What quantities of these two contracts would you recommend buying or selling in order to minimize the 95% expected shortfall for daily profit?

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Next time:

01

Carbon pricing and emissions trading

02

Difficulty of achieving decarbonization of the energy sector

03

Using scenarios in planning (and Least Worst Regret approach)

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