An option analysis of renewable support mechanisms

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Motivation

- Regulation on renewable energy promotion based on **Feed in Tariffs (FiT)** worldwide has proven to be very effective in delivering renewable capacity.
- However, its economic efficiency has been put into question.
- Many countries have already abandoned the FiT system and introduced new schemes based on **auctions**.
- In many auction systems, bids are made for a return on investment of renewable plants (i.e. the **Rate of Return (RoR)** regulation).
- According to the International Energy Agency, 40% of global new wind capacity for the period 2020-25 is expected to be supported by FiT and 35% by auction schemes.
- There is scope for analysis on the *design*, *costs* and *risks* of these two incentive systems.

Outline

- **Introduction**
- **Methodology**
- **Data**
- **Results**
- **Conclusions**

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Development of Electricity from Renewable Sources (RES-E)

- Drivers:
  - Incentive-based regulatory schemes: FiT, RoR, green certificates…
- Drawbacks:
  - High capital costs.
  - High investment risks.
  - Uncertain returns.

Volatility ← **RES-E Intermitency**

Policy benefit evaluation → OPTION PRICING

Potential to evaluate risk mitigation for investors under scenarios of uncertainty

Real options for RES-E incentives valuation

- Boomsma et al. (2012):
  - Effects of market and policy risks under FiT and green certificates in Nordic countries from a real option perspective.
  - Focus on capacity.
- Yu et al. (2006):
  - Real option valuation model to compare the FiT system in Spain with a switchable tariff consisting of market price + incentive.
  - Compound real options.
  - Focus on wind power.
- Haar and Haar (2017):
  - Economic efficiency of incentive mechanisms based on FiT in the European Union by looking at returns to investors.
  - Black and Scholes formula.
  - Focus on capacity.

Research Questions & Contribution

- **How much risk could entail the regulatory schemes to promote RES-E?**
  - Which is the difference between FiT and RoR supports?
  - Which is the role of volatility in this quantified risk?

- Using option price theory,
  - We evaluate the impact of FiT and the RoR regulation on **risk mitigation.**
  - We quantify ex-post the risk that these regulations take away from renewables and pass on to consumers.
  - We quantify the **value of the avoided risk**.

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Two different regulatory systems

Feed in Tariffs	Rate of Return
Guaranteed price that provides a stable income flow (€/MWh)	Guaranteed profit, considering both costs and revenues (€)
Payment over production	Payment over investment
Spain: 2004-2013	Spain: 2014 onwards

Both schemes are **voluntary**, so our *model* can be used to evaluate investment opportunities on RES-E and to estimate the market value if the option to accept the regulation is taken.

Black and Scholes

- Traditional methods do not take into account the uncertainties and flexibilities associated with RES-E projects.
- Option pricing do take these characteristics into account.
- We use the Black and Scholes model to evaluate FiT and RoR interpreted as put options.
- We value the options at the beginning of the year and execute them at the end of the year, when the regulator makes the payment.

Interpreting FiT as real options

- We value the risk of producing 1MWh.
- The option price represents the cost for the buyer's acceptance of the risk.
- The exposure of RES-E investors can be hedged by obtaining a *put option* with exercise price equal to the price of the FiT in €/MWh.

➔ $K = p_{FiT}$

- The price of the underlying asset is measured in €/MWh and computed as the total income of RES-E producers (€) over the total amount of RES-E produced (MWh).

➔ $$S = \frac{\sum_{i=1}^{8760} p_i * qRES_i}{\sum_{i=1}^{8760} qRES_i}$$

Interpreting RoR as a real option

- We value the risk of producing the total MWh of one year.

- RoR regulation implies that a renewable production unit gets a subsidy equal to the operating costs plus a fixed rate of return on capital. Since operating costs are covered, we may ignore them when computing profits.

- The exposure of RES-E investors can be hedged by obtaining a *put option* with exercise price equal to the return on investment in €.

➔ K = return on investment

- The price of the underlying asset is measured in € and computed as the total income of RES-E producers (€) minus the variable cost of the RES-E produced (€).

➔ $S = \sum_{i=1}^{8760} p_i * qRES_i - \sum_{i=1}^{8760} RESvariable\ cost_i$

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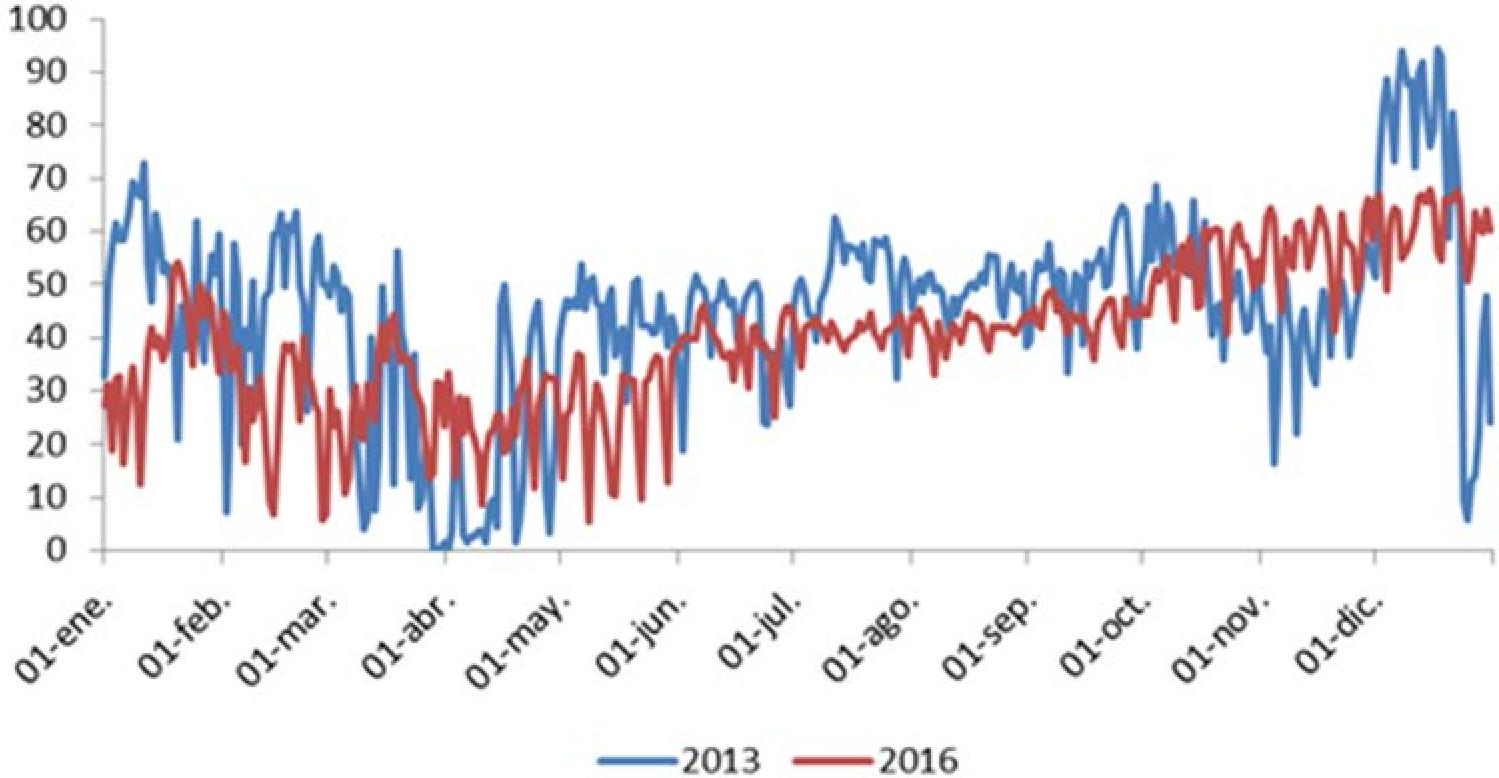
Data Sources

- Day-ahead market prices and aggregate quantities (spot): Spanish electricity market operator (OMIE).
- RES-E quantities by technology: Spanish TSO (REE).
- Incentives to RES-E: Spanish antitrust authority (CNMC).
- Scope:
  - 2013: FiT valuation.
  - 2016: RoR valuation.

Electricity price evolution 2013 and 2016



Source: Own elaboration based on data from OMIE.

Descriptive Statistics on electricity prices

	2013	2016
Mean	45,09	40,25
Median	47,82	41,26
Standard deviation	17,91	13,63
Kurtosis	1,03	-0,23
Skewness	-0,43	-0,14
Minimum	0	5,53
Maximum	94,42	67,85

Source: Own elaboration based on data from OMIE.

RES-E monthly production

Source: Own elaboration based on data from REE.

Renewable Energy and Incentives

2013			
Technology	**Energy under FiT (GWh)**	**Regulated incentive (m€)**	**Regulated incentive (€/MWh)**
CHP	24,880	1,674.77	67.31
Solar FV	8,249	2,889.11	350.22
Solar Thermal	4,326	1,120.75	259.08
Wind	47,884	2,125.44	44.39
Hidropower	5,701	257.75	45.21
Biomass	4,042	335.80	83.08
Waste	3,172	111.32	35.10
Waste treatment	4.444	384.59	86.53
Others	0.28	155	411.99
Total	**102,699**	**8,899.65**	**86.66**

Source: CNMC

Renewable Energy and Incentives

2016				
Technology	**Energy under RoR (GWh)**	**Incentives to investment (m€)**	**Incentives to operation (m€)**	**Variable cost (€/MWh)**
CHP	23,793	58,606	826.612	34,74
Solar FV	7,871	2,284.85	147.238	18,71
Solar Thermal	5,071	1,082.35	193.948	38,25
Wind	34,921	1,254.46	0	0
Hidropower	2,412	77.24	0	0
Biomass	3,394	141.19	137.821	40,61
Waste	3,137	80.39	24.031	7,66
Waste treatment	1,633	888	85.469	52,34
Others	0.18	233	0	0
Total	**82,232**	**4,980.20**	**1.415.119**	**17,21**

Source: CNMC

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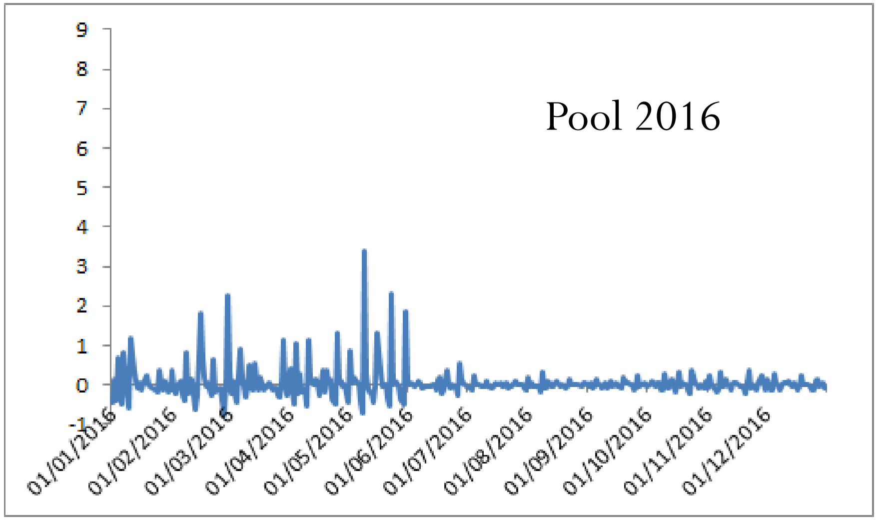
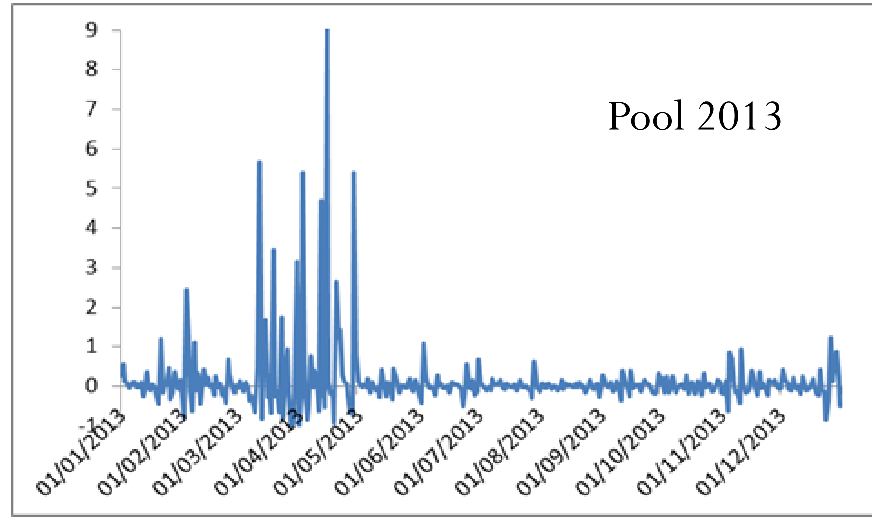
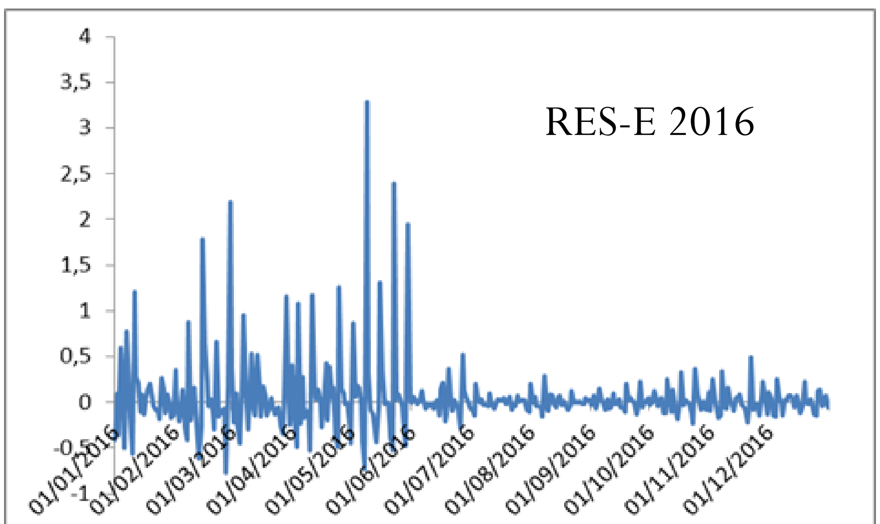
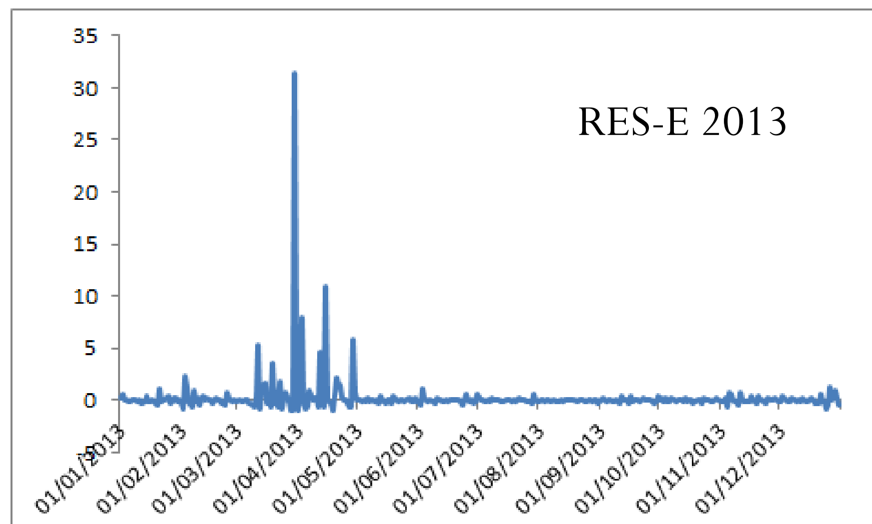
Volatility analysis: Daily price differences

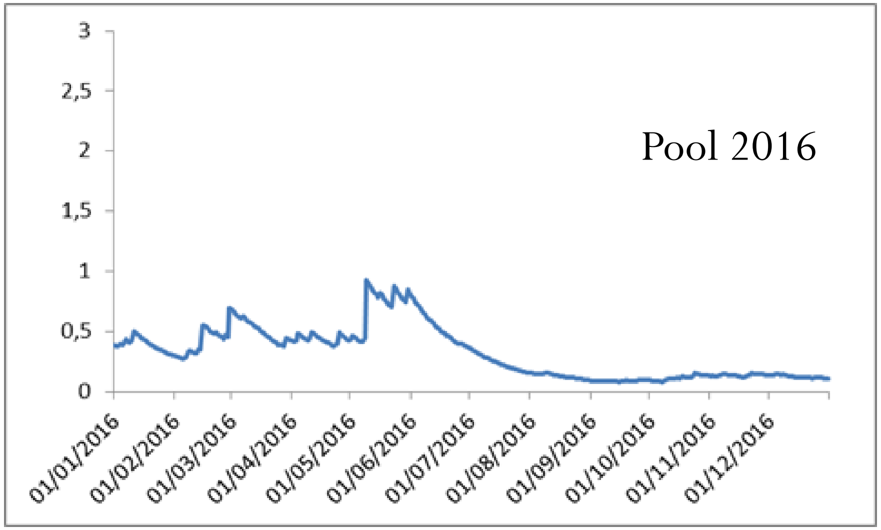


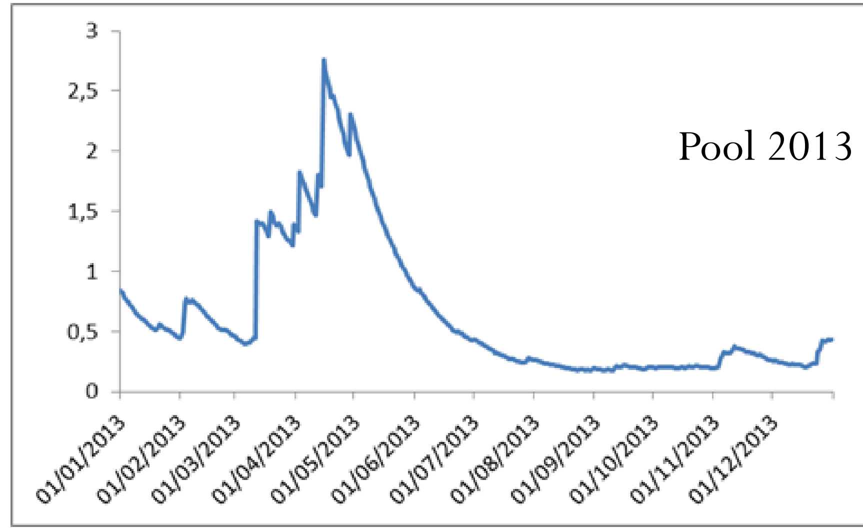


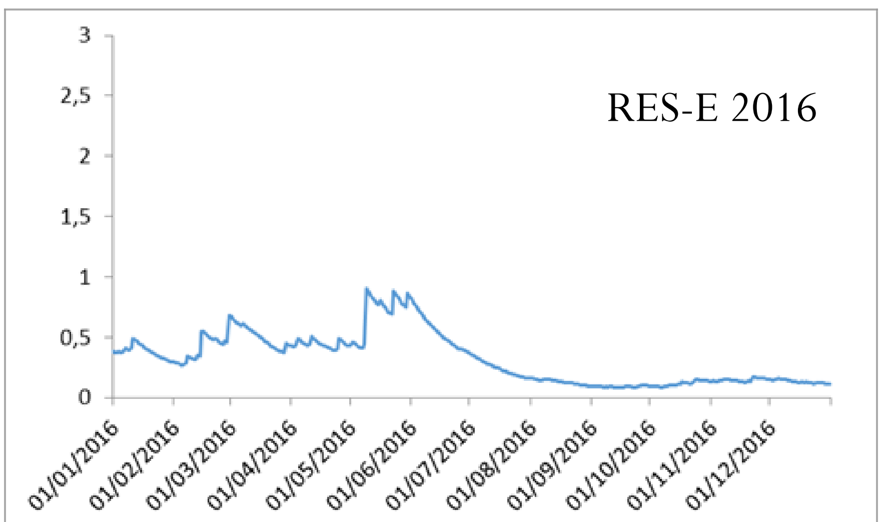


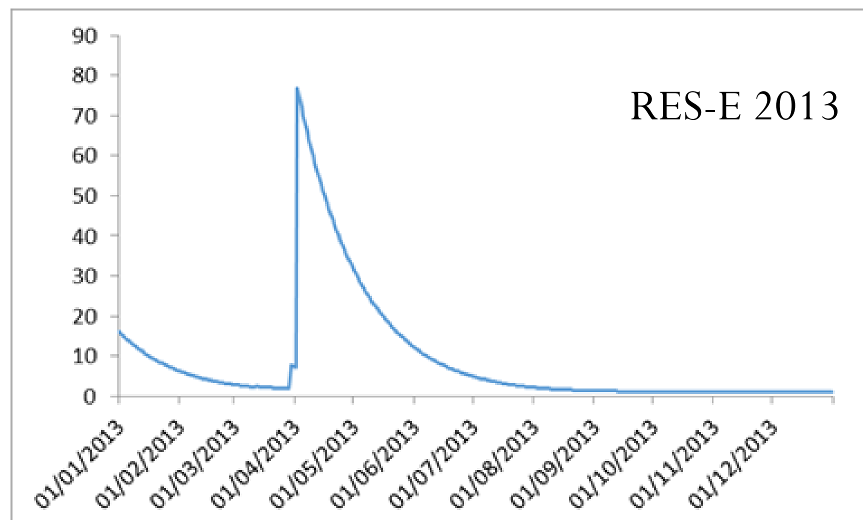


Volatility analysis: EWMA









Black and Scholes: 2013

- In order to evaluate the **FiT** scheme under an option analysis perspective, **we evaluate the risk of 1 MWh produced in 2013**, since FiT remunerate to renewable generators for each MWh sold in the market.
- The subsidy (K) is 77.94 €/MWh,
- The revenue (S) is 41.85 €/MWh.
- The payoff of the option is $K - S = 77.94 - 41.85 = 36.09$€/MWh.
- When we use Black and Scholes model to price this option, we obtain that the price is 43.89 euros per MWh.
- Therefore, the value of eliminating the risk is $43.89 - 36.09 = 7.80$ euros per MWh.
- Considering the total RES-E produced in 2013 corresponds to 856 millions of euros.

Black and Scholes: 2016

- In order to evaluate the **RoR** regulation under an option analysis perspective, **we evaluate the risk of the total amount of MWh produced in 2016**, since the RoR regulation guarantees the subsidy to RES-E generators for their total annual activity.
- The subsidy (K) is 4,980 millions of euros, while the revenue (S) is 3,347 millions of euros.
- The payoff of the option is $K - S = 4,980 - 3,347 = 1,633$ millions of euros.
- When we use Black and Scholes model to price this option, we obtain that the price is 2,269 millions of euros.
- Therefore, the value of eliminating the risk is $2,269 - 1,633 = 636$ millions of euros.

Black and Scholes: FiT vs. RoR

- Comparing both results, we obtain that covering the risk under the FiT system in 2013 is more expensive than under the RoR regulation in 2016 (858 m€ > 636 m€).
- However, since we are comparing two different years, this result could be due to differences in price volatility ($\sigma_{2013} > \sigma_{2016}$).
- In order to eliminate this volatility effect in our Black and Scholes model, we calculate a synthetic put option for 2013 with the volatility of 2016.
- The new put price for 2013 would be 41.33 €/MWh (previously it was 43.89 €/MWh) ➔ the put price reduces under lower volatility values.
- The value of eliminating the risk would then be 576 m€ (previously it was 858 m€).
- Therefore, comparing FITs and RoR regulations with corrected volatilities, we observe that covering the risk under a RoR regulation would be more expensive (636 m€ > 576 m€).

Black and Scholes: Summary

	2013	2016
S (m€)	4,595	3,347
K (m€)	8,558	4,980
σ	0.96	0.81
r	0.0053	0.004
P(S,t) (m€)	**4,819**	**2,269**
K-S (m€)	**3,963**	**1,633**
Eliminated risk (m€)	**856**	**636**
Eliminated risk using lower volatility (m€)	**576**	**636**

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Conclusions

- Our model allows us to compare the cost of eliminating the risk associated to investment in RES-E technologies for two different incentive schemes: FITs and RoR regulation.
- Both regulations transfer part of the risk from producers to consumers.
- The volatility of the pool is due to intermittent RES-E.
- The put in 2013 is more expensive because of the electricity price volatility (more RES-E participation).
- By eliminating the difference in volatility, the put is more expensive in 2016 ➔ higher risk hedging.

- Further research:
  - We are improving our methodology to identify each RES-E technology.
  - We are computing individual put options by technology.
  - We are analysing the period 2007-2020:
    - 2007-2013: FiT scheme
    - 2014- 2020: RoR regulation.

Thank you!

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The Black and Scholes Model

$$C(S,T) = N(d_1)S - N(d_2)Ke^{-r(T-t)}$$

$$d_1 = \frac{1}{\sigma\sqrt{T-t}}[\ln\left(\frac{S}{K}\right) + \left(r + \frac{\sigma^2}{2}\right)(T-t)]$$

$$d_2 = d_1 - \sigma\sqrt{T-t}$$

$$P(S,T) = e^{-r(T-t)} - S + C(S,T)$$

$$P(S,T) = N(-d_2)Ke^{-r(T-t)} - N(-d_1)S$$

C(S,T)	Price of a call option
P(S,T)	Price of a put option
S	Underlying asset spot price
K	Strike price
r	Risk free interest rate (compound annual rate)
σ	Volatilility of the returns of the underlying asset
T-t	Time to maturity
N()	Normal cumulative distribution function