Model Risk and Power Plant Valuation

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Outlook

Motivation and Introduction: Questions

- How significant is the impact of the model's choice on the value of a given instrument?
- How to assess the value of the parameters' uncertainty?
- What is the main driver of the model risk in the energy markets?

General Approach

- We consider the model risk inherent in the valuation procedure of fossil power plants.
- We focus on a gas-fired power plant as flexible and low-carbon source of electricity which is an important building block in terms of the switch to a low-carbon energy generation.
- We model the generated financial streams as the spread option and investigate the reinvestment problem.
- To capture model risk we use a methodology recently established in a series of papers: [Cont, 2006, Bannör and Scherer, 2013].

Risk-Captured Price

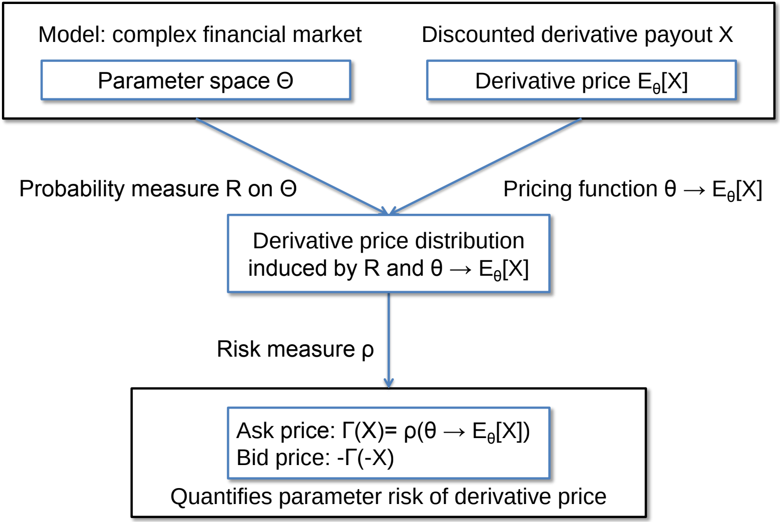
Having

- a contingent claim X,
- a parameter space Θ,
- a distribution R on the parameters,
- a parameterised family of valuation measures $(Q_\theta)_{\theta \in \Theta}$,
- a law-invariant, normalised convex risk measure ρ

results in a **risk-captured price** of a contingent claim X by

$$\Gamma(X) := \rho(\theta \mapsto \mathbb{E}_\theta[X]).$$

Visualisation of the Steps of Parameter Risk-Capturing Valuation



Risk-Capturing Functional: AVaR Example

- Define AVaR w.r.t. the significance level $\alpha \in (0, 1)$ of some random variable X as

$$AVaR_\alpha(X) = \frac{1}{\alpha} \int_0^\alpha q_X(1-\beta) d\beta,$$

- where $q_X(\gamma)$ is γ quantile of the random variable X.
- The AVaR measures the risk which may occur according to the previously specified model Q_θ.
- When calculating the parameter risk-captured price of X being induced by the AVaR, risk-neutral prices $(\mathbb{E}_\theta[X])_{\theta\in\Theta}$ w.r.t. different models $(Q_\theta)_{\theta\in\Theta}$ are compared and subsumed by the AVaR risk measure. Hence, the AVaR is used to quantify the parameter risk we are exposed to when pricing X.

Clean Spark Spread Option and Virtual Power Plant

- We model the daily profit (or loss) of the virtual power plant position as

$$V_t = \max\{P_t - hG_t - \eta E_t, 0\},$$

- P_t - is the power price;
- G_t - is the gas price;
- E_t - is the carbon certificate price;
- h - is the heat rate of the power plant;
- η - CO_2 emission rate of the power plant.

Energy Price Models

Let

- $(\Omega, \mathbb{P}, \mathcal{F}, \mathbb{F}_{t, t\in[0,T]})$ be a complete filtered probability space;
- **carbon price**

$$dE_t = \alpha^E E_t\, dt + \sigma^E E_t\, dW_t^E;$$

- **gas price**

$$G_t = e^{g(t)+Z_t},$$
$$dZ_t = -\alpha^G Z_t\, dt + \sigma^G dW_t^G;$$

- **power price**

$$P_t = e^{f(t)+X_t+Y_t},$$

base signal: $dX_t = -\alpha^P X_t\, dt + \sigma^P dW_t^P,$

spike signal: $dY_t = -\beta\, Y_t\, dt + J_t\, dN_t.$

- **dependence structure**

W^E, W^G and N are mutually independent processes,

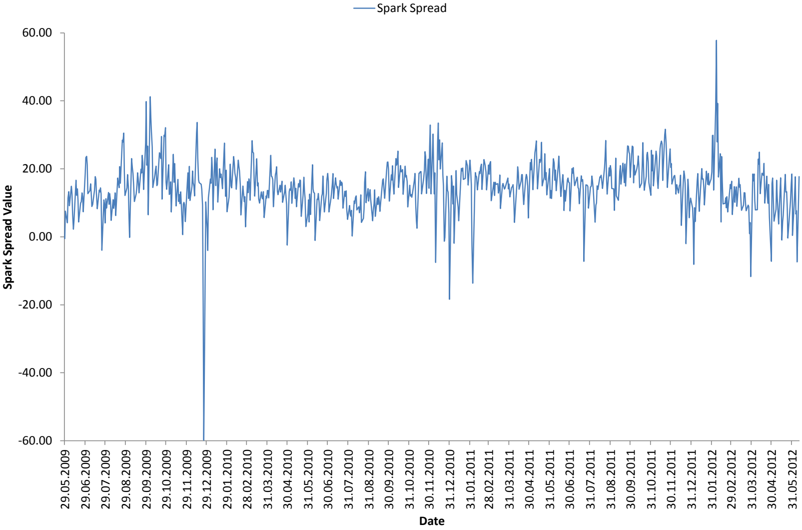
$$dW_t^P\, dW_t^G = \rho\, dt.$$

Data

- **Phelix day base**: It is the average price of the hours 1 to 24 for electricity traded on the spot market. It is calculated for all calendar days of the year as the simple average of the auction prices for the hours 1 to 24 in the market area Germany/Austria, EUR/MWh.
- **NCG daily price**: Delivery is possible at the virtual trading hub in the market areas of NetConnect Germany GmbH & Co KG, EUR/MWh.
- **Emission certificate daily price**: One EU emission allowance confers the right to emit 1 tonne of carbon dioxide or 1 tonne of carbon dioxide equivalent, EUR/EUA.
- **Observation period**: 25.09.2009 - 08.06.2012.

Power, Gas, and Carbon Prices, 25.09.2009 - 08.06.2012

Clean Spark Spread, 25.09.2009 - 08.06.2012



Estimating the Model Parameters

- Estimation of the seasonal trends and deseasonalisation of power and gas.
- Separation of the power base and spike signals.
- Estimation of the mean-reverting rates.
- Estimation of the power base signal X_t.
- Estimation of the spike signal Y_t.
- Estimation of the correlation.

Following the above steps, we estimate the set of parameters with mainly an MLE approach

$$\{\alpha^E, \sigma^E, g(t), \alpha^G, \sigma^G, f(t), \alpha^P, \beta, \sigma^P, \lambda, \mu_s, \sigma_s, \rho\}.$$

General Procedure: Step 1

- After estimating all the parameters of our prices, we simulate them for the future time period and compute for every day t the spark spread value V_t given as

$$V_t = \max\{P_t - hG_t - \eta E_t, 0\}.$$

- Then, by fixing all the parameters except for the chosen one and setting the shift value ξ (e.g. 1%), we compute shifted up and down spark spread values as

$$V_t^{up}(\theta + \xi),$$

$$V_t^{down}(\theta - \xi).$$

General Procedure: Step 2

- We compute the value of the power plant (VPP) by means of Monte Carlo simulations. For fixed large N and $T = 3$ years we have

$$VPP(t,T) = \frac{1}{N}\sum_{i=1}^{N} VPP_i(t,T),$$

$$VPP_i(t,T) = \int_t^T e^{-r(s-t)} V_i(s)\,ds.$$

- For the chosen shift ξ we also compute

$$VPP^{up}(t,T;\theta) = VPP(t,T;\theta+\xi),$$

$$VPP^{down}(t,T;\theta) = VPP(t,T;\theta-\xi).$$

General Procedure: Step 3

- We continue with sensitivity measuring of the VPP w.r.t. the parameter θ with the central finite difference [Glasserman, 2004]

$$\nabla_\theta VPP(t,T) := \frac{\partial VPP}{\partial \theta} = \frac{VPP^{up}(t,T;\theta) - VPP^{down}(t,T;\theta)}{2\xi}$$

- Finally, we compute the bid and ask prices by using a closed-form approximation formula for the AVaR to get the risk-captured prices by subtracting and adding risk-adjustment value to $VPP(t,T)$ respectively. This risk-adjustment value is computed as

$$\frac{\varphi(\Phi^{-1}(1-\alpha))}{\alpha}\sqrt{\frac{(\nabla_\theta VPP)' \cdot \Sigma_\theta \cdot \nabla_\theta VPP}{N}},$$

denoting by Σ_θ the asymptotic covariance matrix of the estimator for the parameter θ [McNeil et al., 2005].

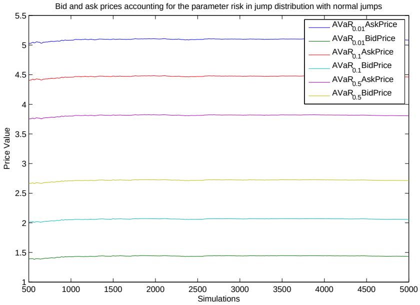
Risk Values Results

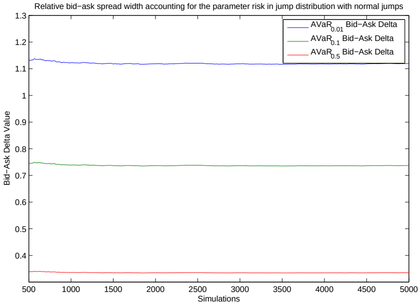
- parameter risk in spike size: Laplace and Gaussian distributions;
- parameter risk in correlation;
- parameter risk in gas signal;
- joint parameter risk in gas and base power signal;
- joint parameter risk in gas, power and emissions (all processes except of jump size parameter).

Resulting values for the relative width of the bid-ask spread for various model risk sources. $\alpha_1 = 0.01$ (the highest risk-aversion), $\alpha_2 = 0.1$, $\alpha_3 = 0.5$

		Jumps size distribution					
		Gaussian			Laplace		
		α_1	α_2	α_3	α_1	α_2	α_3
Model Risk	Jumps	111.9%	73.71%	33.51%	163.5%	107.7%	48.96%
	Correlation	6.95%	4.58%	2.08%	3.29%	2.17%	0.99%
	Gas and power base	6.48%	4.27%	1.94%	3.07%	2.02%	0.92%
	Gas	6.11%	4.03%	1.83%	2.89%	1.91%	0.87%
	Gas, power and carbon	8.21%	5.41%	2.46%	3.83%	2.52%	1.15%

Parameter-risk implied bid-ask spread w.r.t. jump size distribution: Gaussian





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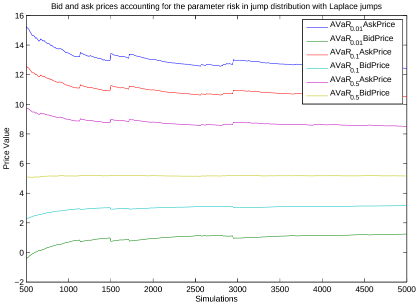
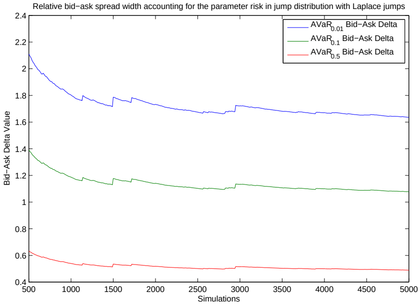
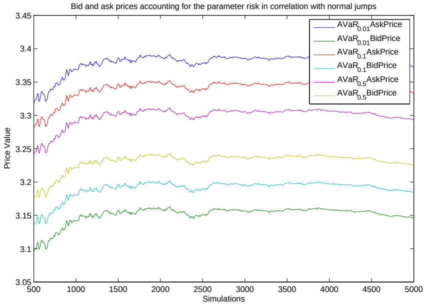
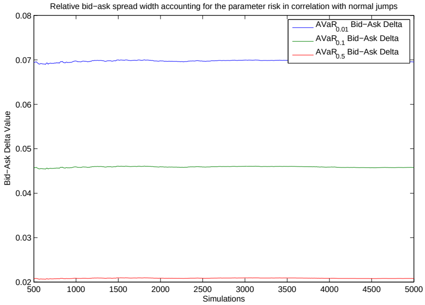
Parameter-risk implied bid-ask spread w.r.t. jump size distribution: Laplace





Parameter-risk implied bid-ask spread w.r.t. correlation parameter, Gaussian jumps





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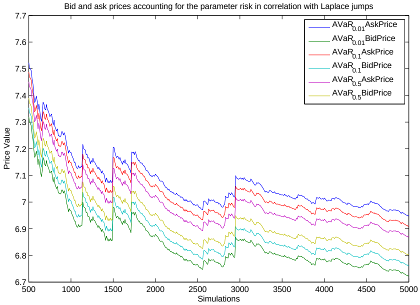

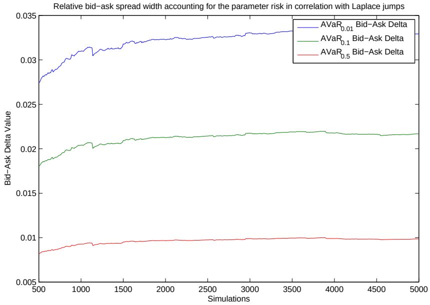

Conclusive Remarks

- We suggested a methodology to quantify model risk in power plant valuation approaches (spread options).
- We studied various sources of risks and found out that the correlation and spike risks are dominating in the energy sector.
- We managed to estimate the lower boundary for the total model risk in terms of the chosen model.
- Future possible application in the energy markets could be a generation of an hourly power forward curve and valuation procedures for storages.

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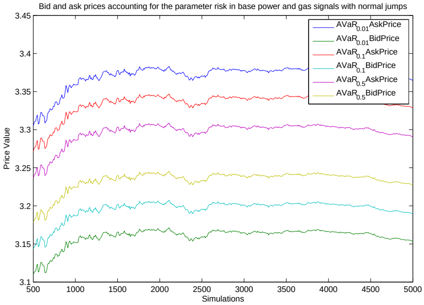
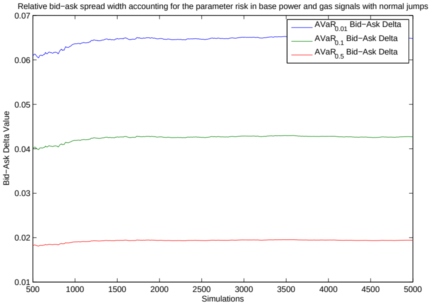
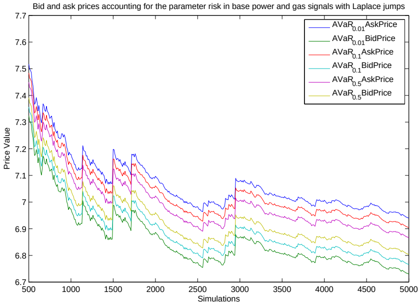
Thank you for your attention!

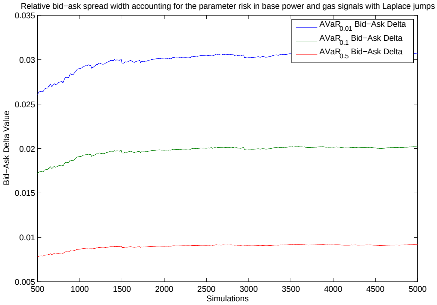
Parameter-risk implied bid-ask spread w.r.t. the gas and power base processes, Gaussian jumps



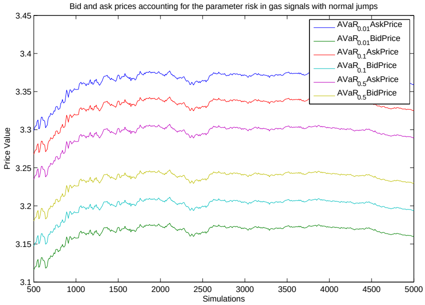


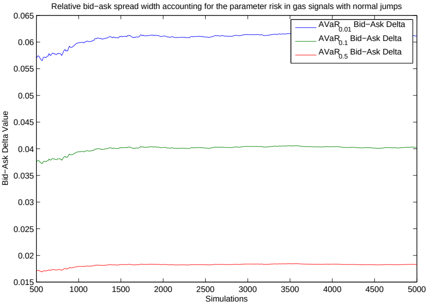
Parameter-risk implied bid-ask spread w.r.t. the gas and power base processes, Laplace jumps



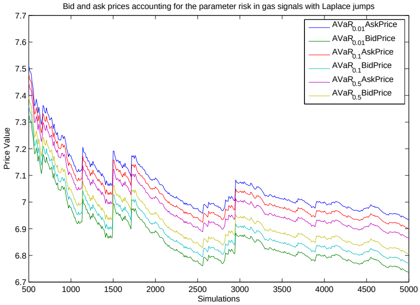


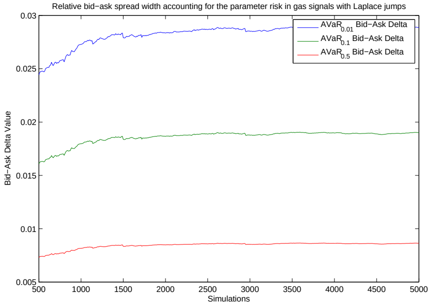
Parameter-risk implied bid-ask spread w.r.t. the gas price process, Gaussian jumps



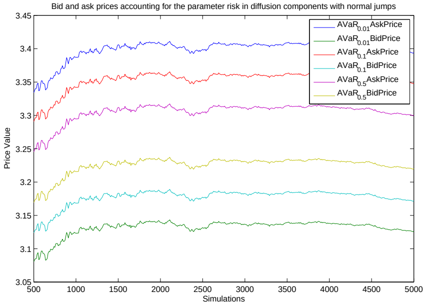


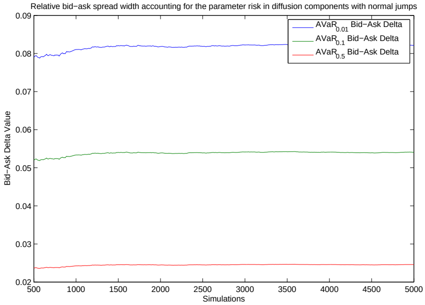
Parameter-risk implied bid-ask spread w.r.t. the gas price process, Laplace jumps





Parameter-risk implied bid-ask spread w.r.t. all the parameters, except of the Gaussian jump size





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Parameter-risk implied bid-ask spread w.r.t. all the parameters, except of the Laplace jump size