Potsdam Institute for Climate Impact Research

Risk aversion in electricity markets: impacts on investment decisions under different hedging strategies

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Leibniz Association

Motivation

Debate about **efficient risk allocation in electricity markets with respect to renewables** (e.g. IEA RETD TCP 2016; Neuhoff et al. 2016; Newbery 2016).

“Fossil generators enjoy a natural hedge as they set the electricity price, and shift the volatility in fuel, carbon and electricity prices […] on to most zero-carbon generators” Newbery (2016)

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The argument:

Capital intensive plants (RES) face higher risks

+

Risk has a higher impact on capital intensive plants since it increases the capital costs

+

Risk markets are incomplete

=

Underinvestment in capital intensive plants

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However, so far equilibrium analysis about this (incl. hedging) is lacking…

Motivation

Risk-reducing strategies

1. **Plant portfolio diversification:** use correlation between plant profits (*cp. Tietjen, Pahle, Fuss 2016*)
2. **Forward contracts:** hedge profits via long-term contracts
3. **Vertical integration:** use correlation between production and retail segment

Motivation

Risk-reducing strategies

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Research question:

What is the impact of these strategies on investment decisions (RES vs. FOS)?

Related literature:

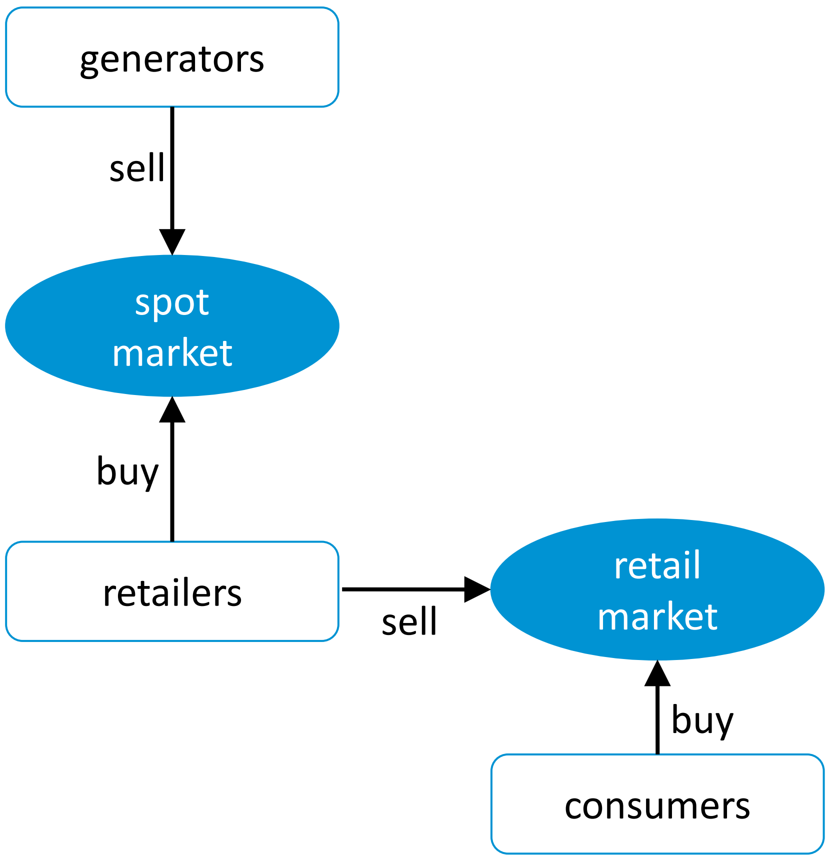
- Focus on impacts of risk aversion on **investment decisions** (*Ehrenmann & Smeers 2011; Fan et al. 2010, 2012*).
- Focus on **forward trading** (*Bessembinder & Lemon 2002; Willems & Morbee 2010*) and **vertical integration** (*Aïd et al. 2011*) but **only for demand-induced risks**. Empirical papers find that forward **risk premium is also affected by fuel and carbon price risks** (e.g. *Daskalakis & Markellos 2009; Redl & Bunn 2013*).

Outline

1. The model – general setup
2. Model analysis
   a) No risk-reducing strategy
   b) Plant portfolio diversification
   c) Forward trading
   d) Vertical integration
3. Conclusion

The Model

General setup – firms and markets



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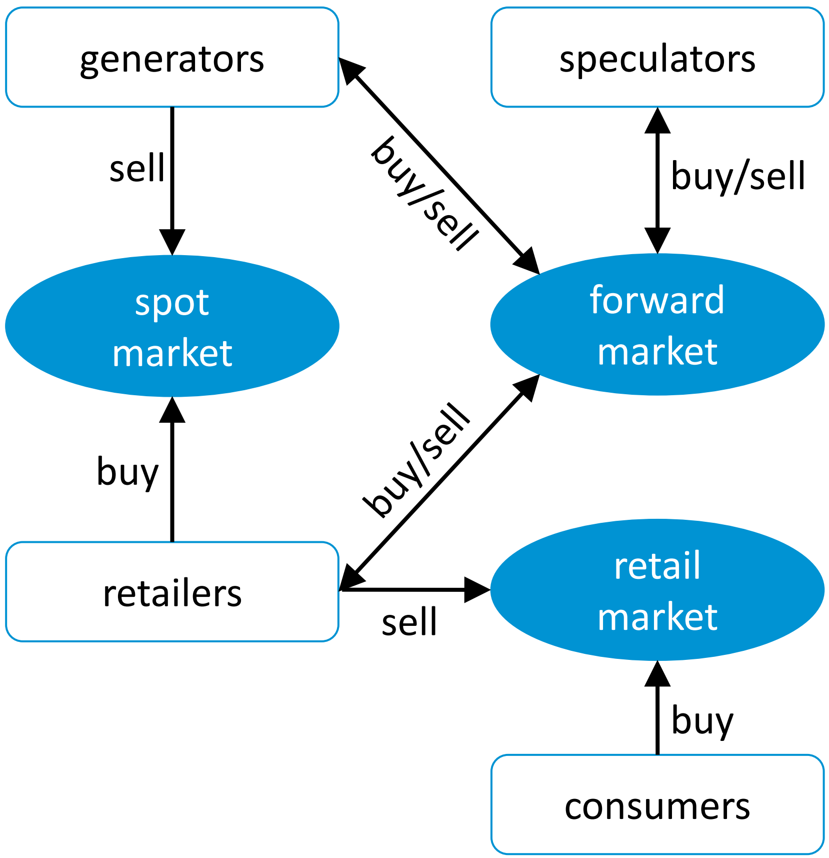

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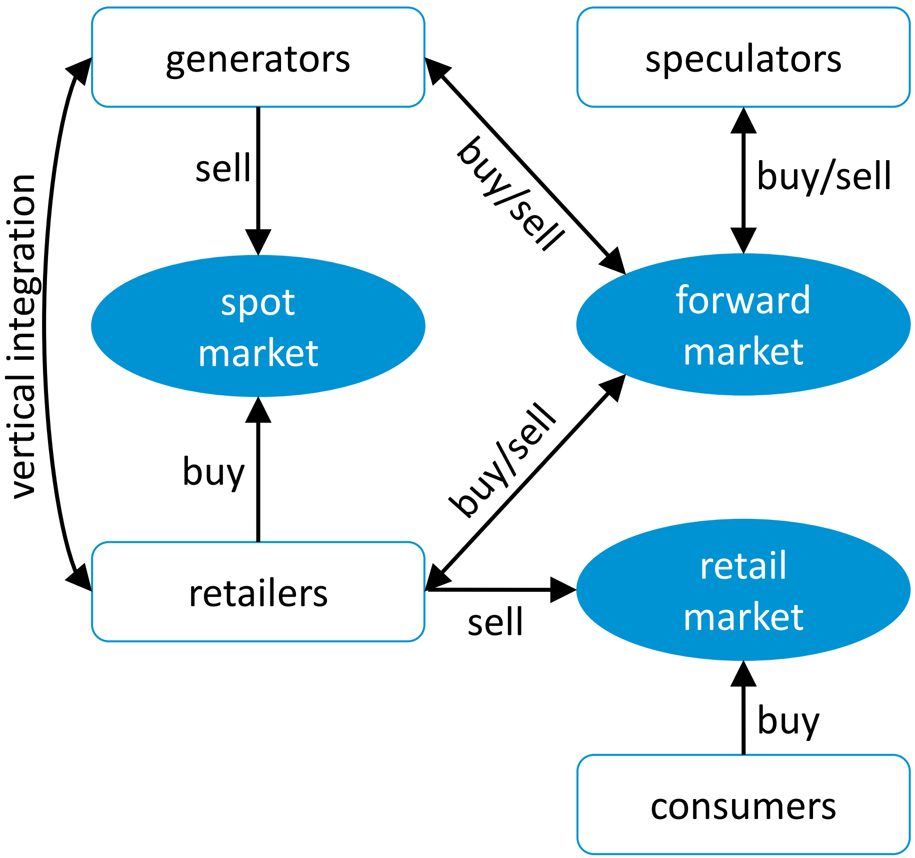

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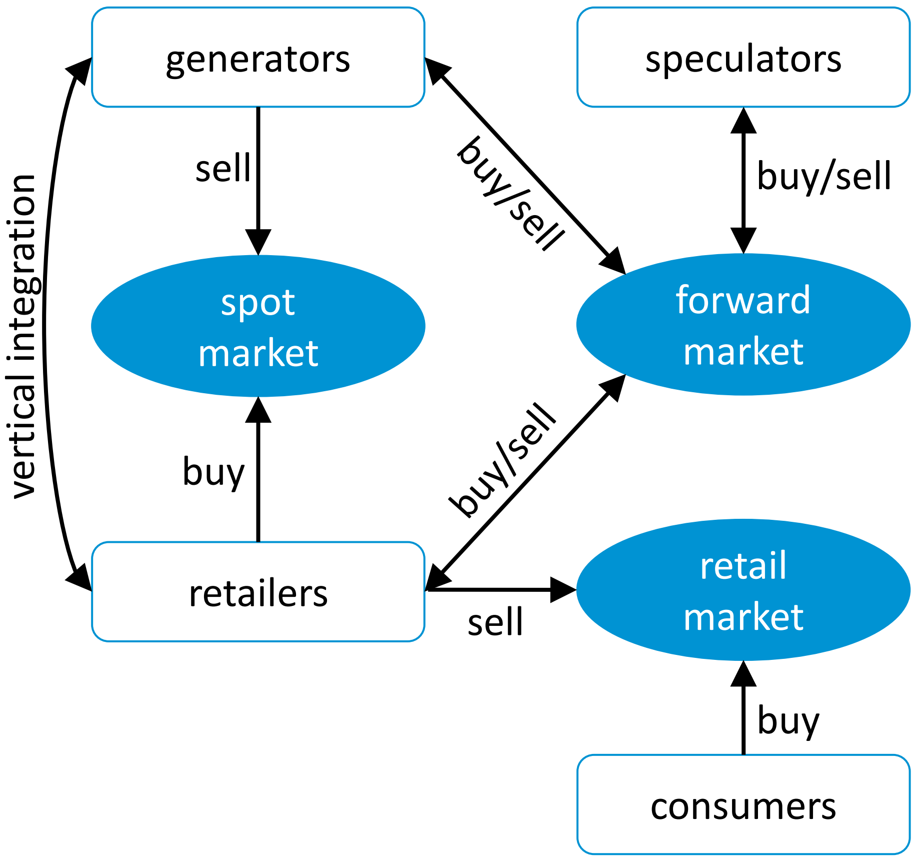

- Perfect competition
- Model stages:
  - 1st stage: investment, retail and forward market decisions under uncertainty
  - 2nd stage: production and consumption (spot market), uncertainty is resolved

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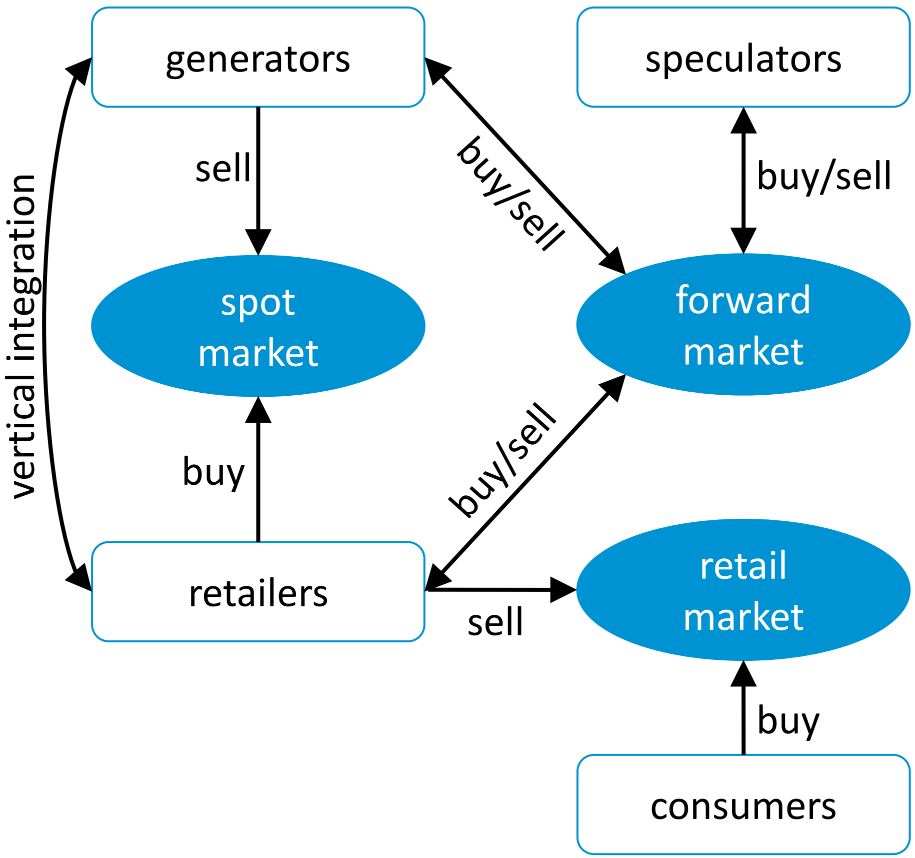

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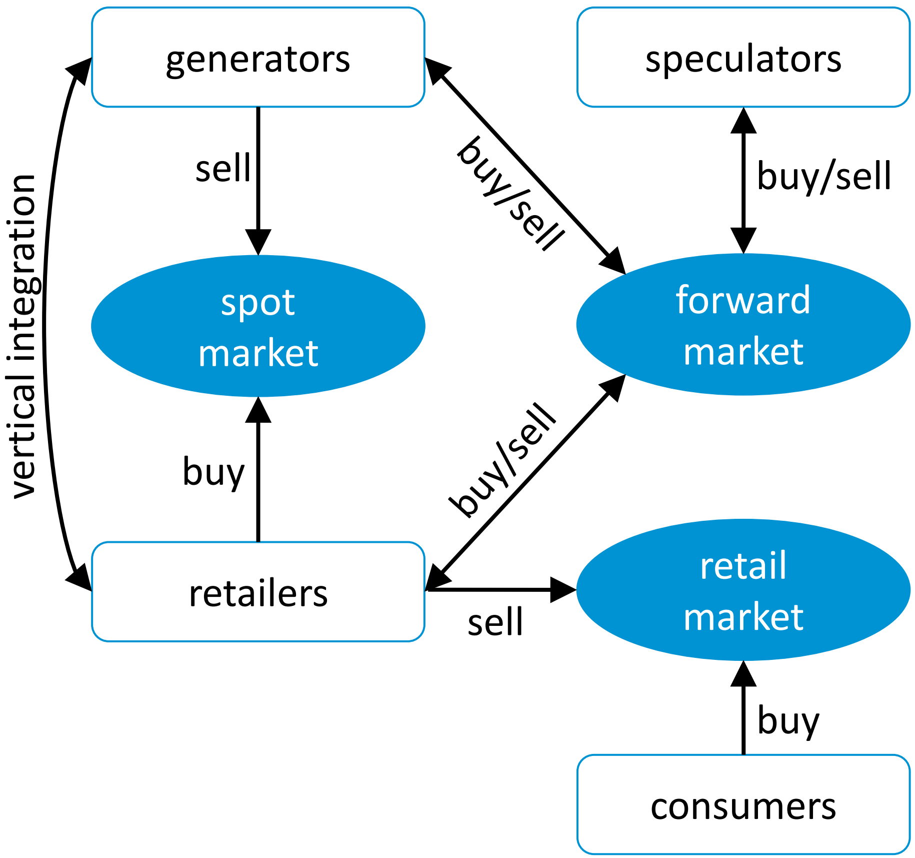

- Perfect competition
- Model stages:
  - o 1^{st} stage: investment decisions under uncertainty
  - o 2^{nd} stage: retail and forward market decisions under uncertainty
  - o 3^{rd} stage: production and consumption (spot market), uncertainty is resolved
- Risk allocation is incomplete:
  - o Not all risk factors are traded
  - o (In-)sufficient time span of forward market

The Model

Firms: producer (pr), retailer (rt), integrated firm (in), speculator (sp), $g = pr, rt, in, sp$

2nd stage: spot market

The Model

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2nd stage: spot market

- **Producers:** max profit π^{pr} via generation level $q_{t,i}$ in each period t of each plant type i:

$$\begin{aligned} c_i - p_t^s + \mu_{t,i} \geq 0 \quad &\perp \quad q_{t,i} \geq 0 \\ k_i av_{t,i} - q_{t,i} \geq 0 \quad &\perp \quad \mu_{t,i} \geq 0 \end{aligned}$$

- Since: $$\mu_{t,i} = \begin{cases} 0, & if\, q_{t,i} < k_i av_{t,i} \\ p_t^s - c_i, & if\, q_{t,i} = k_i av_{t,i} \end{cases}$$

  π^{pr} can be written as:

$$\pi^{pr} = \sum_{t,i} \mu_{t,i} av_{t,i} k_i - ic_i k_i$$

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- **Retailers:** buy electricity to serve consumer demand $d_t(p^{rt})$

- **Equilibrium:** the wholesale spot price p_t^s satisfies:

$$\sum_i q_{t,i} = D_t(p_t^s, p^{rt})$$

  Total consumer demand D_t depends on the spot p_t^s and flat retail p^{rt} price.

The Model

1st stage (index t skipped for simplicity)

- Uncertainty about market outcomes: $\tilde{c}_i, \tilde{d}, \tilde{p}^s$ and thus profits $\tilde{\pi}^g$ are risky.
- **I consider only marginal cost $\tilde{\boldsymbol{c}}_{\boldsymbol{i}}$ induced uncertainties!**

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- Each firm g maximizes expected utility:

$$E[u^g] = E[\pi^g] - \frac{\lambda}{2} Var[\pi^g]$$

  λ: coefficient of absolute risk aversion.

- **Risk-neutral ($\lambda = 0$) benchmark condition for plant investments:**

$$E[\mu_i a v_i] - i c_i = 0$$

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Four cases with risk averse producers ($\lambda > 0$):

1. **No risk-reducing strategy**
2. **Plant portfolio diversification**
3. **Forward trading**
4. **Vertical integration**

For simplicity, I just consider one *RES* and one *FOS* plant.

Model analysis

1. No risk-reducing strategy

- Optimal investment decisions:

$$k_i^* = \frac{E[\mu_i av_i] - ic_i}{\lambda Var[\mu_i av_i]} \qquad \lambda Var[\mu_i av_i]\text{: marginal costs of risk}$$

- Since $var[\pi_{res}] > var[\pi_{fos}]$, **risk averse firms underinvest in RES**

Model analysis

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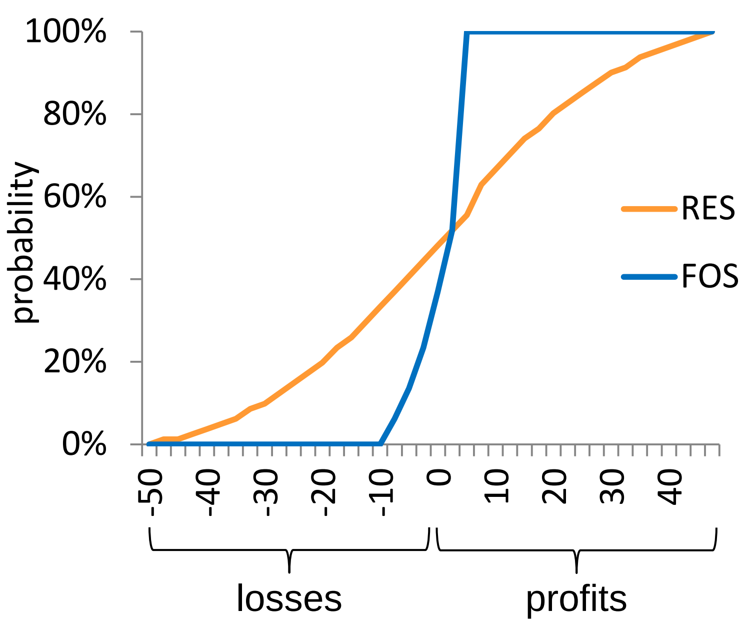
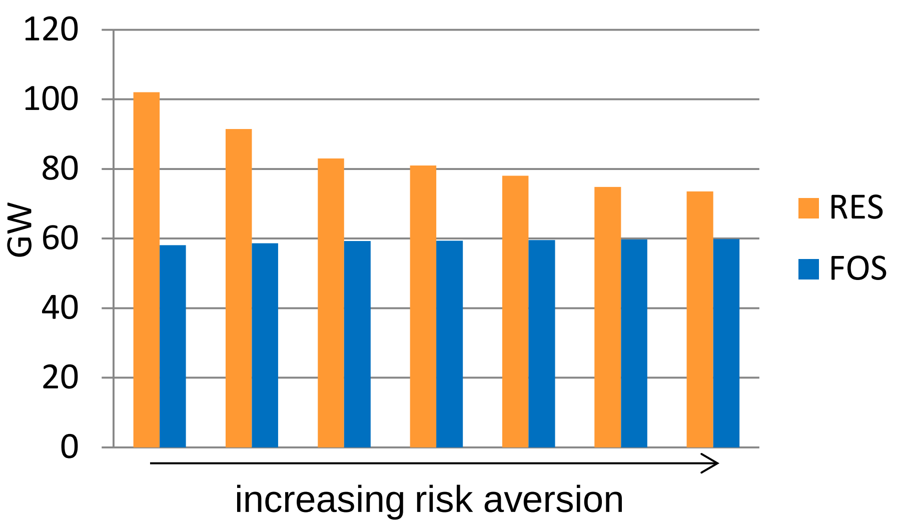
Distribution of RES and FOS profits



Equilibrium capacities



Model analysis

2. Plant portfolio diversification

- Firms additionally consider the **covariance between plant profits:**

$$k_i^* = \frac{E[\mu_i av_i] - ic_i}{\lambda Var[\mu_i av_i]} - \frac{\sum_j Cov[\mu_i av_i\, ; \mu_j av_j] k_j}{Var[\mu_i av_i]} \text{ with } j \neq i$$

- Given that the risk is driven by the marginal costs of the fossil plants $\tilde{c}_{fos}$:

$$Cov[\mu_{res} av_{res}\ ;\ \mu_{fos} av_{fos}] < 0$$

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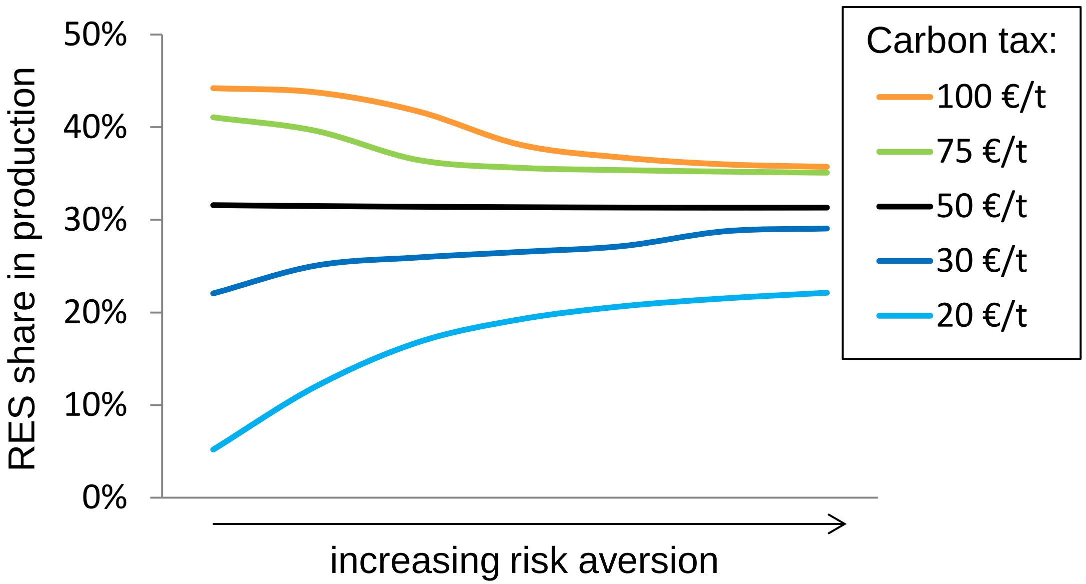

- At **low RES shares**:
  overinvestment in RES compared to the risk neutral benchmark
- At **high RES shares**:
  underinvest in RES compared to the risk neutral benchmark
- At some **threshold RES share:**
  risk aversion has **no effect**

Model analysis

3. Forward trading

Producers:

$\tilde{\pi}_i^{pr} = \tilde{\mu}_i a v_i k_i - i c_i k_i + \left(p^f - \tilde{p}^s\right) f_i$

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Optimal forward positions:

$$f_i^* = \underbrace{\frac{p^f - E[p^S]}{\lambda Var[p^S]}}_{\text{Speculation}} + \underbrace{\frac{Cov[\mu_i av_i\,; p^S] k_i}{Var[p^S]}}_{\text{Hedging}}$$

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Retailers:

$$\tilde{\pi}^{rt} = (p^{rt} - \tilde{p}^s)\tilde{d}\alpha + \left(p^f - \tilde{p}^s\right) f_{rt}$$

Optimal forward positions:

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Ignoring speculation motive…

…**RES firms sell forwards**, $f_{res}^* > 0$, because $Cov[\mu_{res} av_{res}\ ;\ p^s] > 0$

…**FOS firms buy forwards**, $f_{fos}^* < 0$, because $Cov\left[\mu_{fos} av_{fos}\ ;\ p^s\right] < 0$

…**retailers buy forwards**, $f_{rt}^* < 0$, because $Cov[(p^{rt} - p^s)d;\ p^s] < 0$

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Given the forward market equilibrium, $f_{res}^* + f_{fos}^* + f_{rt}^* + f_{sp}^* = 0$, the risk premium is

$$p^f - E[p^s] = -\frac{\Lambda}{4}\left(Cov[\mu_{res} av_{res}; p^s] k_{res} + Cov\left[\mu_{fos} av_{fos}; p^s\right] k_{fos} + Cov[(p^{rt} - p^s)d; p^s]\right)$$

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- The sign of the risk premium is determined by the **hedging pressure**:
  $p^f - E[p^s] < 0$ if the need for reducing risk is **higher for RES** than for FOS + retailer
  $p^f - E[p^s] > 0$ if the need for reducing risk is **lower for RES** than for FOS + retailer

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- Optimal investment decisions:

$$k_i^* = \frac{1}{\lambda\left(1-r_i^2\right)}\left(\frac{E[\mu_i av_i] - ic_i}{Var[\mu_i av_i]} + \frac{Cov(\mu_i av_i; p^S)E\left[p^f - p^S\right]}{Var[\mu_i av_i]Var[p^S]}\right)$$

$r_i^2 \in [0; 1]$: correlation between plant profits π_i^{pr} and price p^s.

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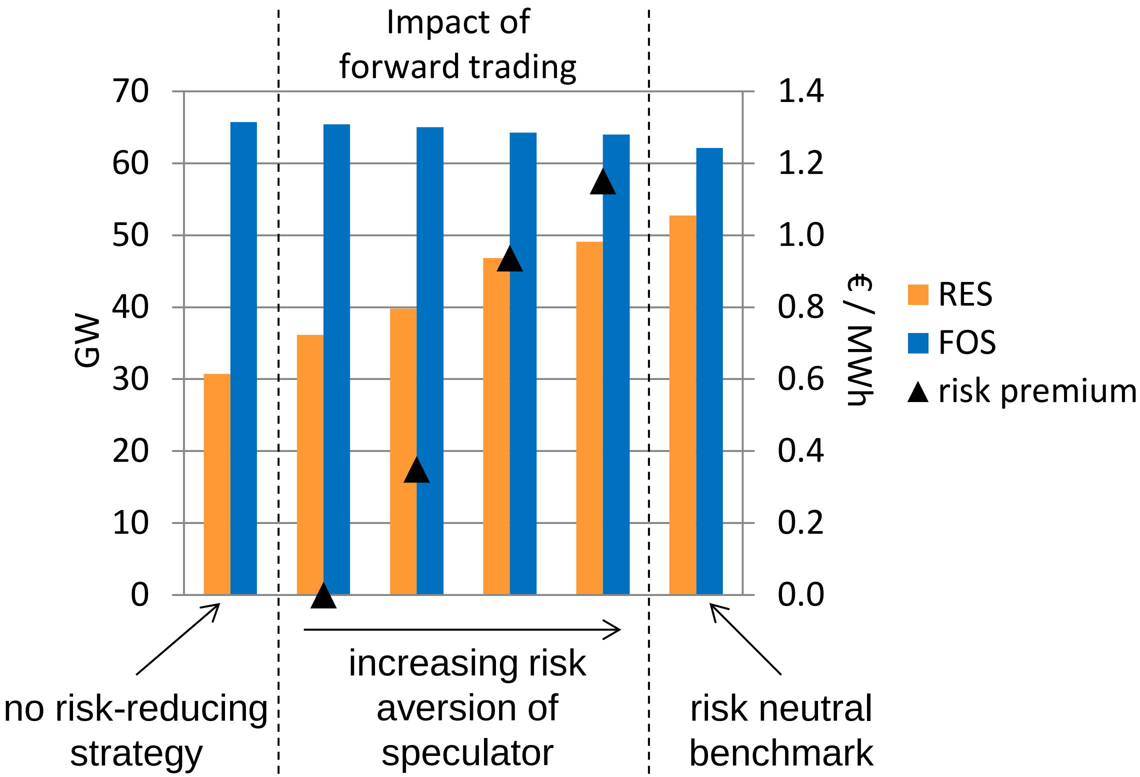
$r_i^2 \in [0; 1]$: correlation between plant profits π_i^{pr} and price p^s.
Therefore, if the demand-side is sufficient risk averse such that $p^f - E[p^s] > 0$ holds:
investments in RES increase with the risk premium.

Potentially, firms invest more in RES compared to the risk neutral benchmark.

Model analysis

3. Forward trading



Model analysis

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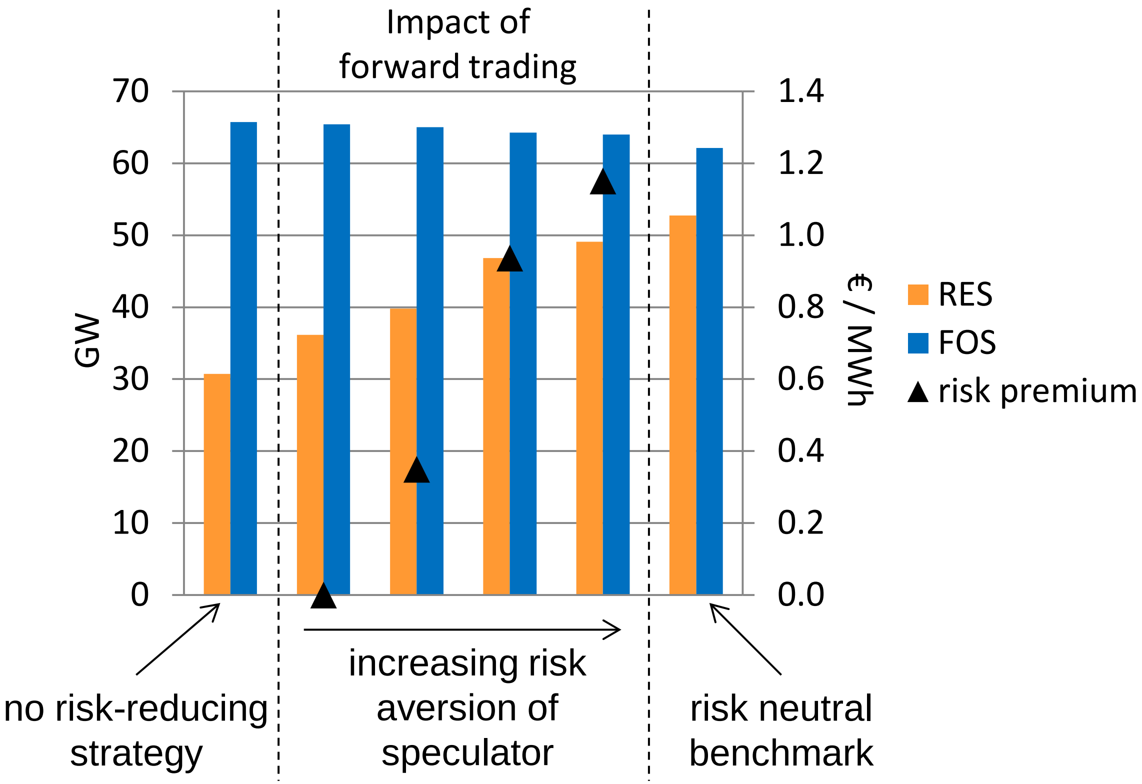

Here: forward market does not cover whole life time of the plants

Model analysis

4. Vertical integration

- Optimal retail decisions:

$$\alpha_i^* = \frac{E[(p^{rt} - p^s)d]}{\lambda_i Var[(p^{rt} - p^s)d]} - \frac{Cov[\mu_i av_i ;(p^{rt} - p^s)d]k_i}{Var[(p^{rt} - p^s)d]}$$

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  vertical integration with RES is more beneficial.

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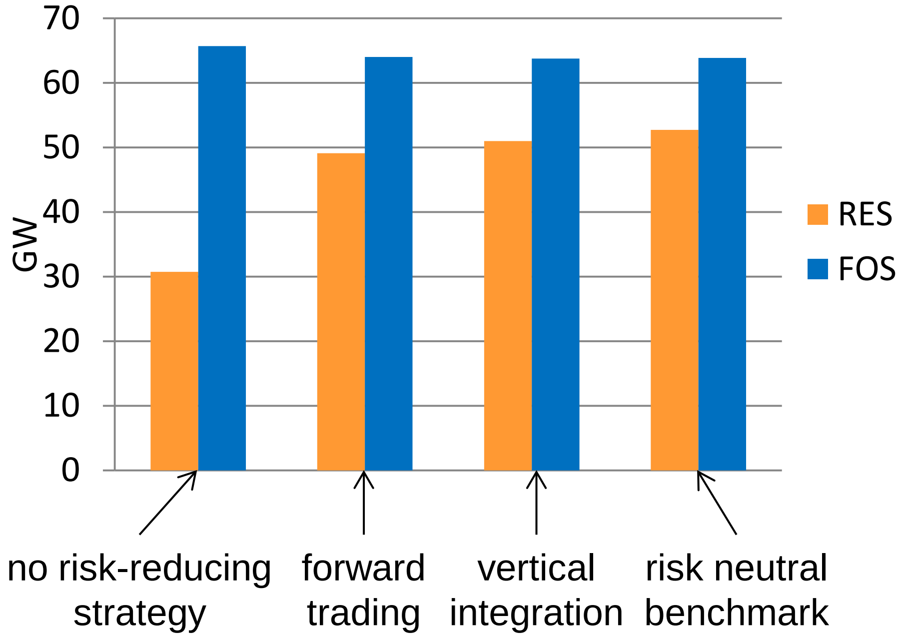

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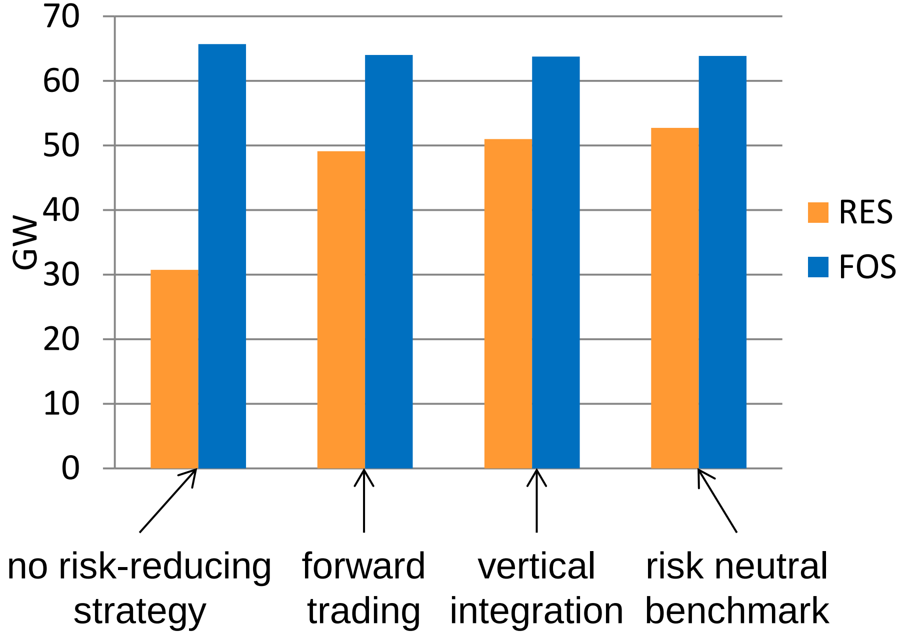

The more often the retail price is adjusted, the less beneficial is vertical integration.

Conclusion

Indeed, **risk aversion can lead to underinvestment in RES, but at least large firms**

- with different plant types in their portfolio
- which are vertically integrated

also have incentives to **invest more in RES due to risk.**

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Ideal way: improve risk markets

- consumers hedging demand increases RES share even above risk neutral share
- support efficient risk allocation (e.g. reduce transaction costs, market maker obligations)
- last resort: regulatory determined long-term contracts

Thank you!

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