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The Role of Hedging in Carbon Markets

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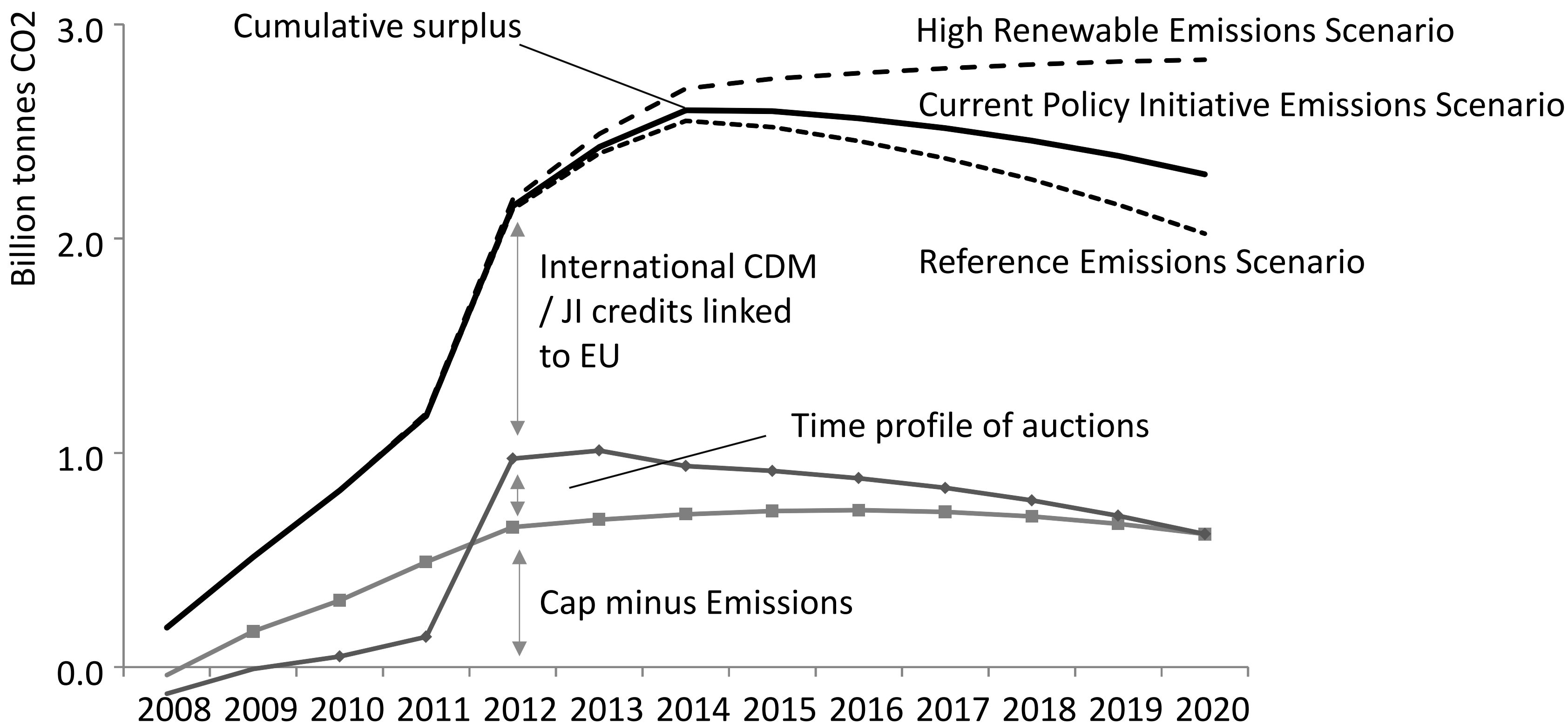
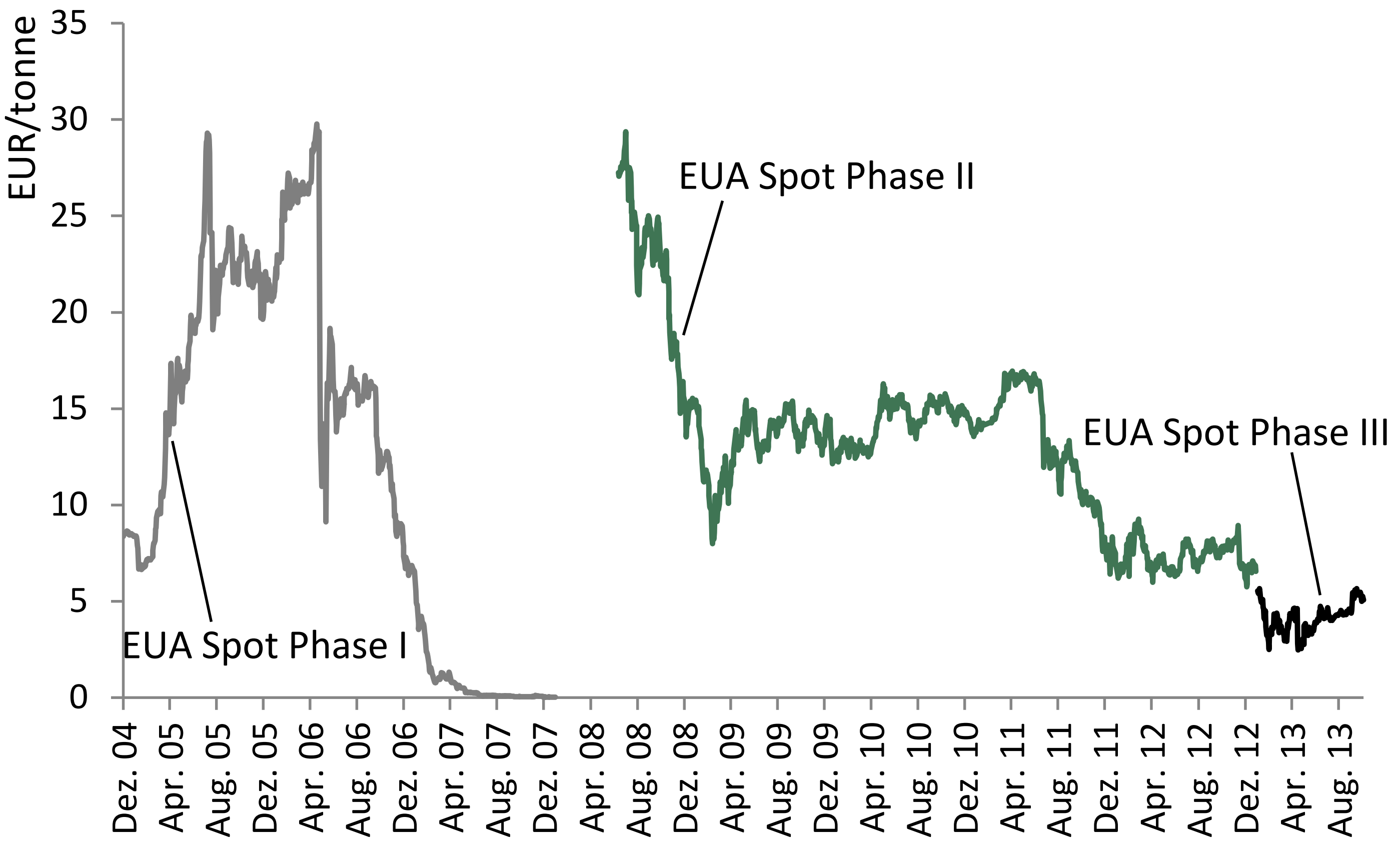
Surplus has accumulated



Source: Neuhoff, Schopp, Boyd, Stelmakh, and Vasa (2012)

Carbon price in Phase II did not drop to 0 because of allowance banking



Source: EEX

Background on EU Emissions Trading Scheme

Definition of Banking: To hold CO2 allowance from one year to the next instead of using it to cover emissions

Actors that bank CO2 allowances:

- Power sector: sells power on forward contracts up to four years in advance and buy in parallel fuel inputs and CO2 to hedge
- Industry sector: banks free allowances that are not needed to cover annual emissions
- Banks: bank allowances and sell forward contracts at 3-5% to cover cost of capital
- Speculative investors: bank allowances if they can realise their required rate of return 10-15%

Emitter/ Hedger

Arbitrageur/ Speculator

Source: Neuhoff, Schopp, Boyd, Stelmakh, and Vasa (2012)

2 Research question and approach

1. **How do EU power generators use their flexibility to adjust CO_2 hedging volume?**

   Interviews with 13 power generators on CO_2 hedging strategies

   Analytic model of flexibility of CO_2 hedging volume

2. **How does the behavior of CO_2 emitters, hedgers and speculators impact carbon prices?**

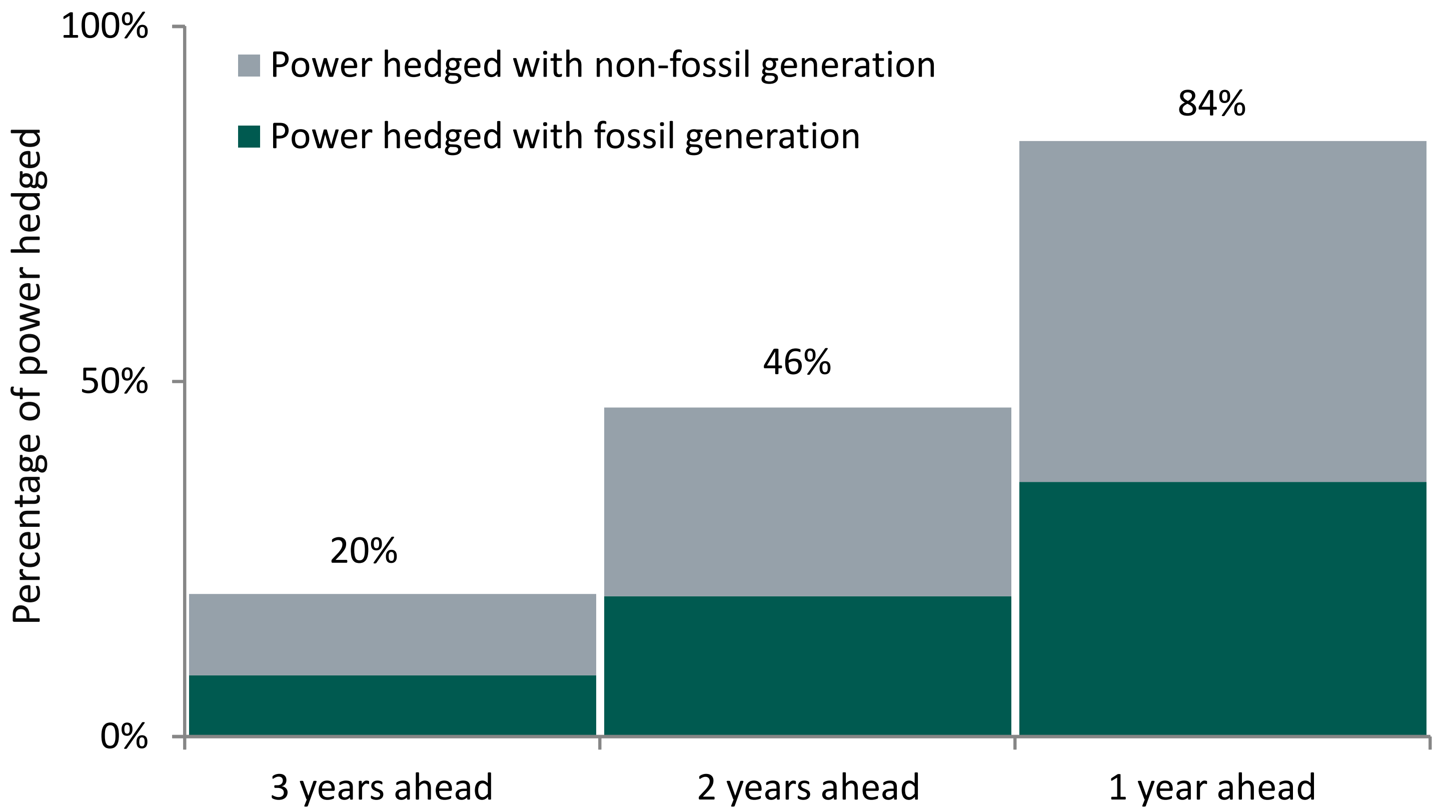
   Model of market equilibrium with CO_2 emitters, hedgers and speculators

3 Literature

- **Banking:** Theory and empirical evidence show intertemporal efficiency of banking in emissions trading schemes (Rubins 1996, Ellerman and Montero 2007)
- **Optimization of power generation portfolios:** Kleindorder and Li (2011) identify optimal portfolios of physical and financial power generation assets by maximising expected profits minus penalty term for value at risk
- **Models of emissions trading between speculators and emitting firms:** Colla, Germain, and Van Steenberghe (2012) find that speculators tend to stabilise prices by absorbing risk

4 Model I: Flexibility of CO_2 hedging volume

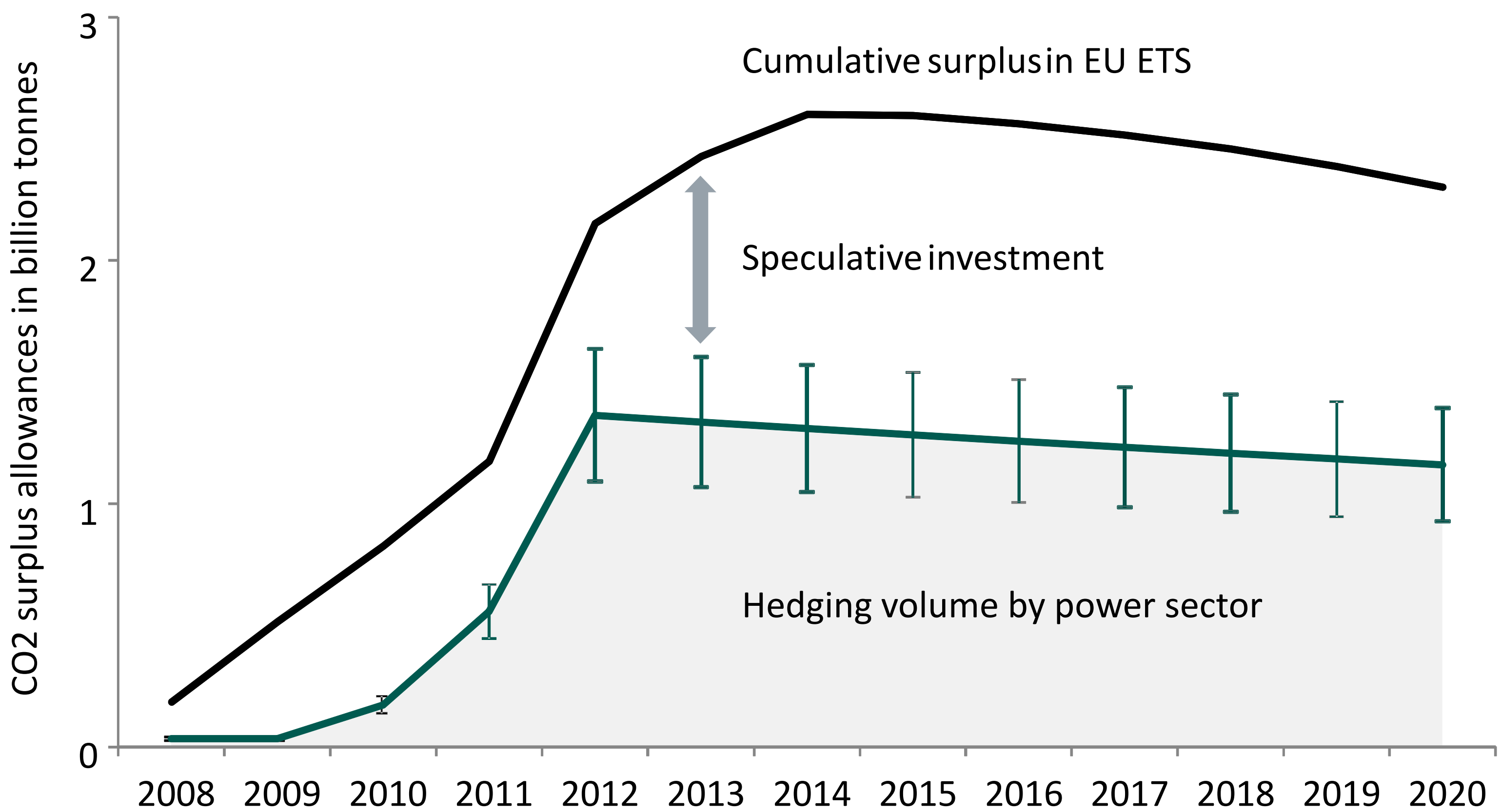
Aggregate hedging schedule

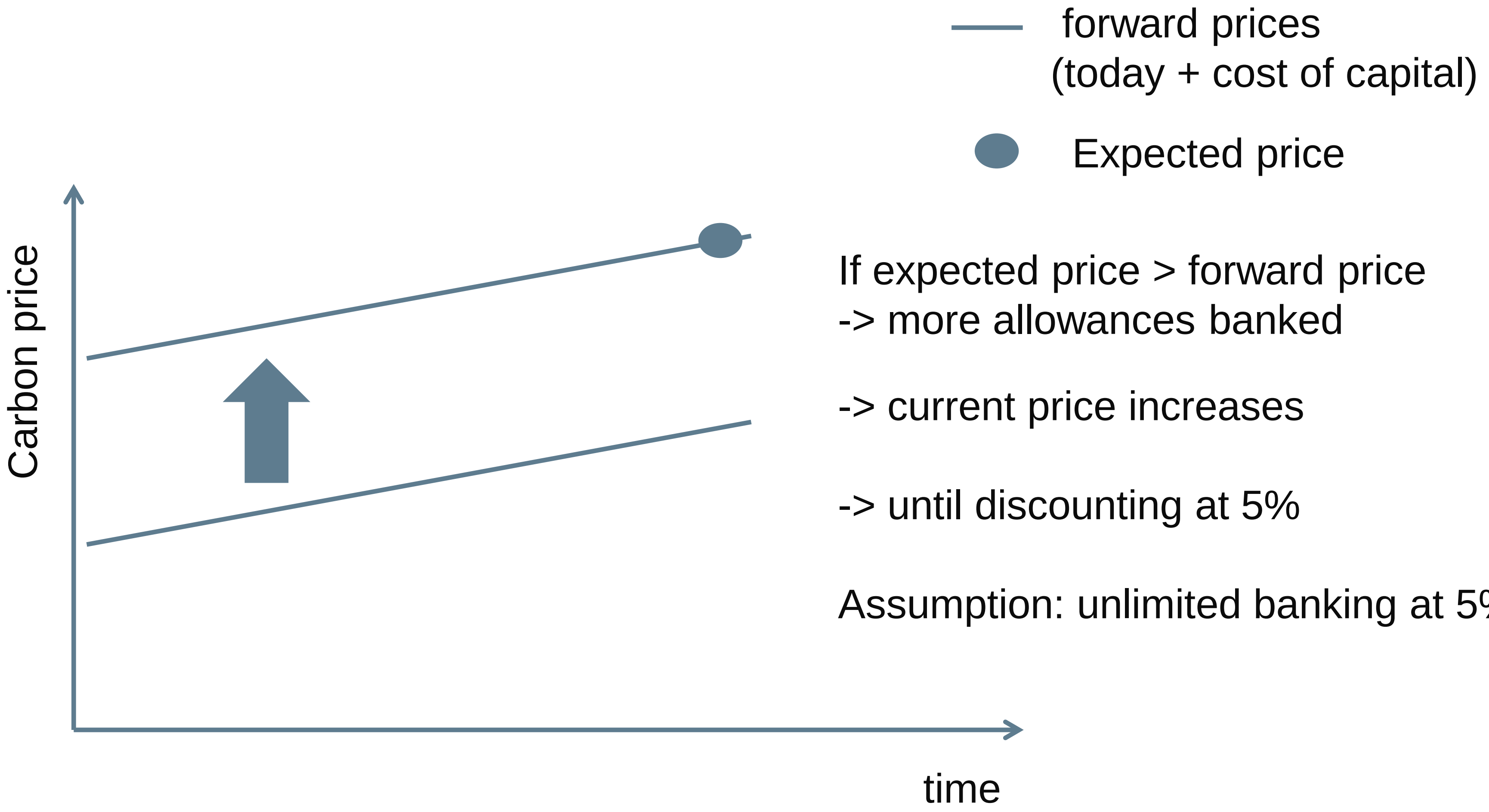


Source: Annual reports 2011, Eureelectric 2010

Model I: Flexibility of CO_2 hedging volume

Additional surplus allowances need to be banked as speculative investment



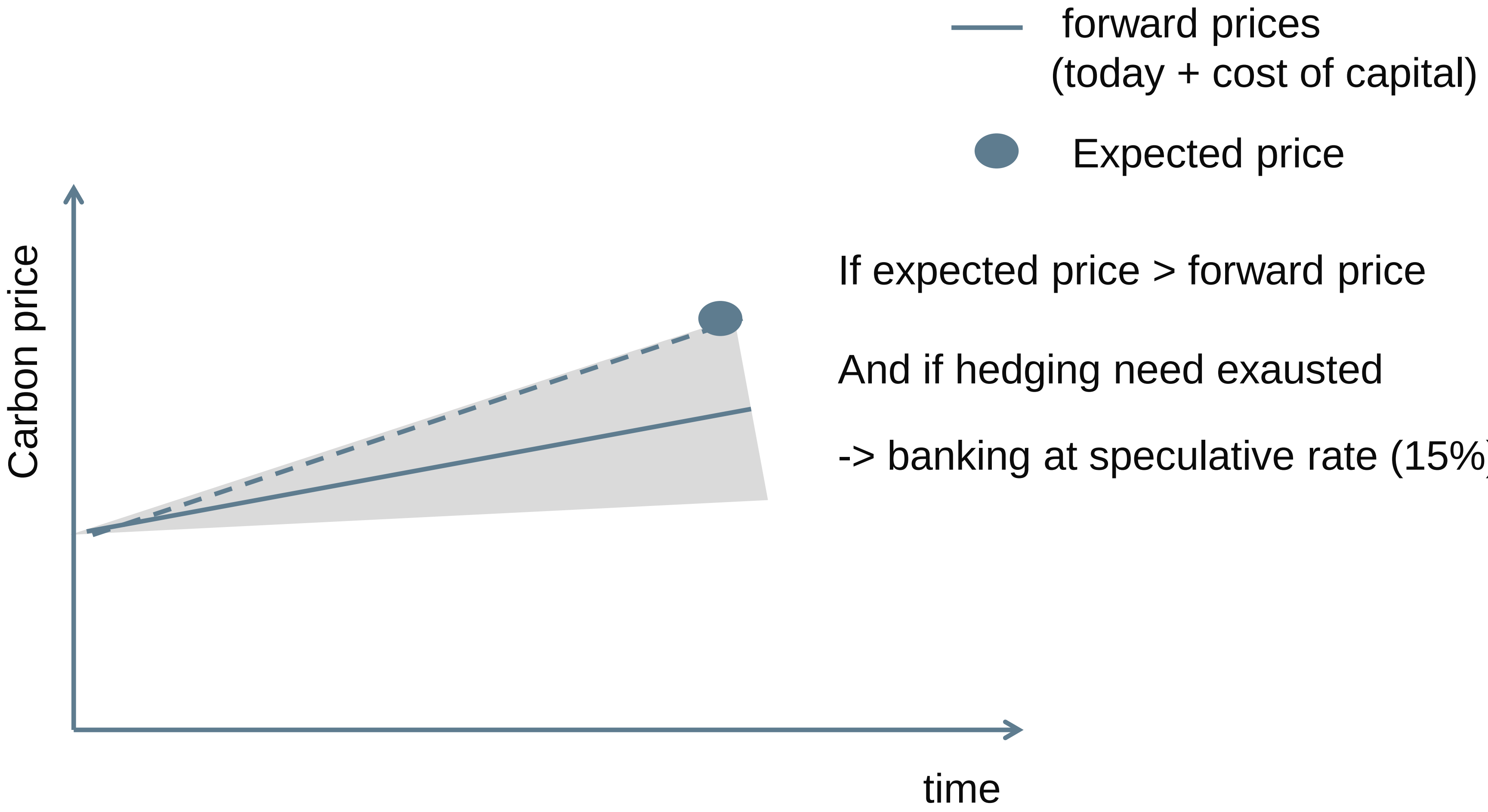


If expected price > forward price
-> more allowances banked

-> current price increases

-> until discounting at 5%

Assumption: unlimited banking at 5%



If expected price > forward price

And if hedging need exausted

-> banking at speculative rate (15%)

Forward price can differ from expected price
(as long as difference insufficient to attract speculation)

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Model I: Flexibility of CO2 hedging volume

Firm' s objective function - :

$$\max_{c_1, g_1} \quad e_1\, p_1^e + (E - e_1)\, E(p_2^e)$$

$$- \left(c_1 \frac{p_1^c}{f^c} + (C - c_1) \frac{E(p_2^c)}{f^c} + g_1 \frac{p_1^g}{f^g} + (G - g_1) \frac{E(p_2^g)}{f^g} \right)$$

$$- \left(c_1\, i_{CO2}^c\, p_1^{CO2} + (C - c_1)\, i_{CO2}^c E(p_2^{CO2}) + g_1\, i_{CO2}^g\, p_1^{CO2} + (G - g_1)\, i_{CO2}^g\, E(p_2^{CO2}) \right)$$

$$- \left(\alpha((\gamma_1\, C - c_1)^2 + (\gamma_1\, G - g_1)^2) \right)$$

s.t. $e_1 = c_1 + g_1\,,\ \ C \geq c_1,\ \ G \geq g_1$

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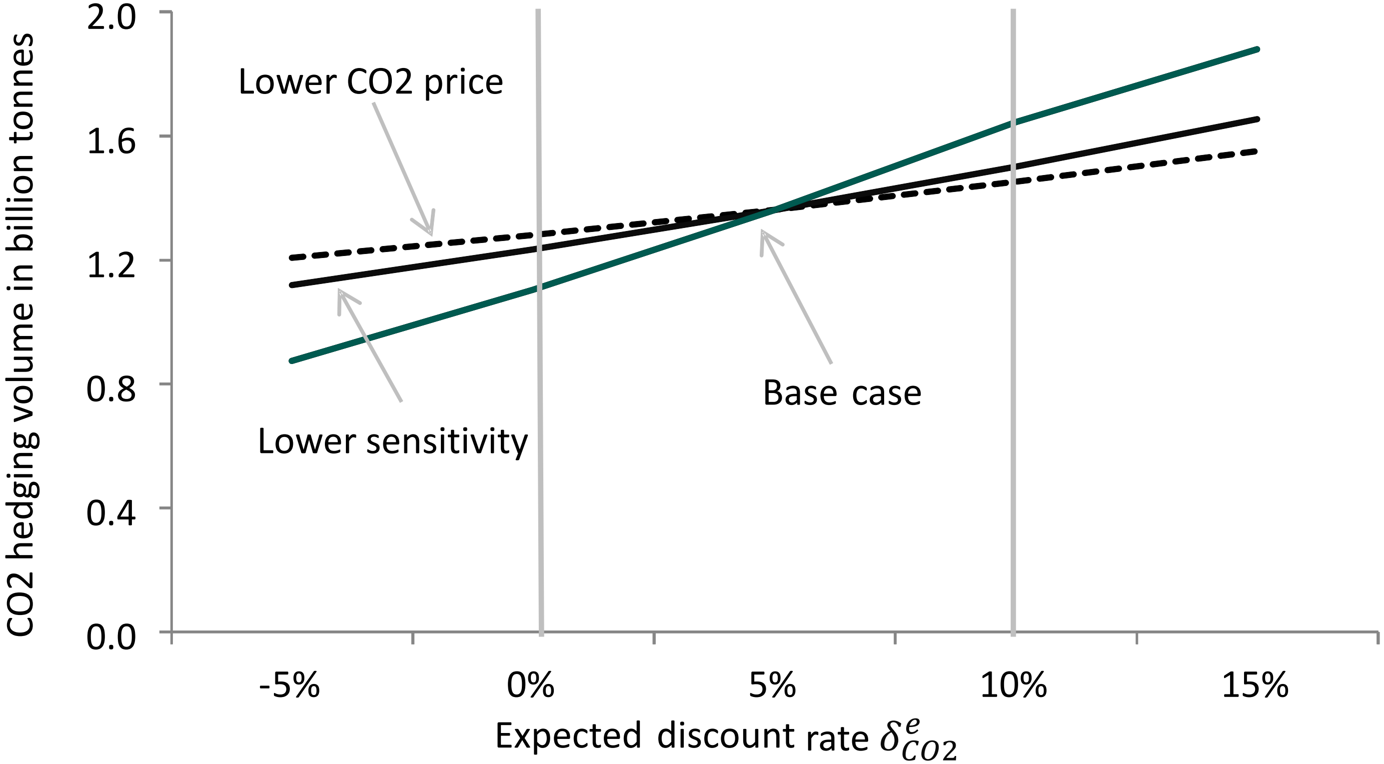
Model I: Flexibility of CO2 hedging volume

Aggregate CO2 hedging corridor ranges between 1.1 and 1.7 billion tonnes



	Base case	Lower CO2 price	Lower sensitivity
p_1^{CO2}	20€/tCO2	7.5€/tCO2	20€/tCO2
α	$E(p_2^{CO2}) + 1$ €/tCO2 →10% ΔQ_1^h	$E(p_2^{CO2}) + 1$ €/tCO2 →10% ΔQ_1^h	$E(p_2^{CO2}) + 2$ €/tCO2 →10% ΔQ_1^h

5 Model II: Market equilibrium with CO2 hedgers, speculators and emitters

Equilibrium in period 1:

$$\boldsymbol{Q_1^{surplus} = Q_1^h + Q_1^s}$$

Equilibrium in period 2:

$$\boldsymbol{Q_2^{surplus} = -Q_1^h - Q_1^s}$$

3 actors in carbon market:

Emitters $Q_1^{surplus} = \theta_1 + \beta * p_1^{CO2}$

Emission responsiveness

Hedgers $Q_1^h = \gamma * (C * i_{CO2}^c + G * i_{CO2}^g) + \frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha}\left(\frac{p_1^{CO2}(1+\delta_{CO2}^e)}{(1+\delta_{CO2}^m)} - p_1^{CO2}\right)$

Hedging schedule

Deviations of CO2 forward prices from expectations

Speculators $Q_1^s = \max\left(\varphi\left(E(p_2^{CO2})/(p_1^{CO2}) - 1 - \delta_{CO2}^s, 0\right)\right) = 0$

Speculative responsiveness

Required rate of return

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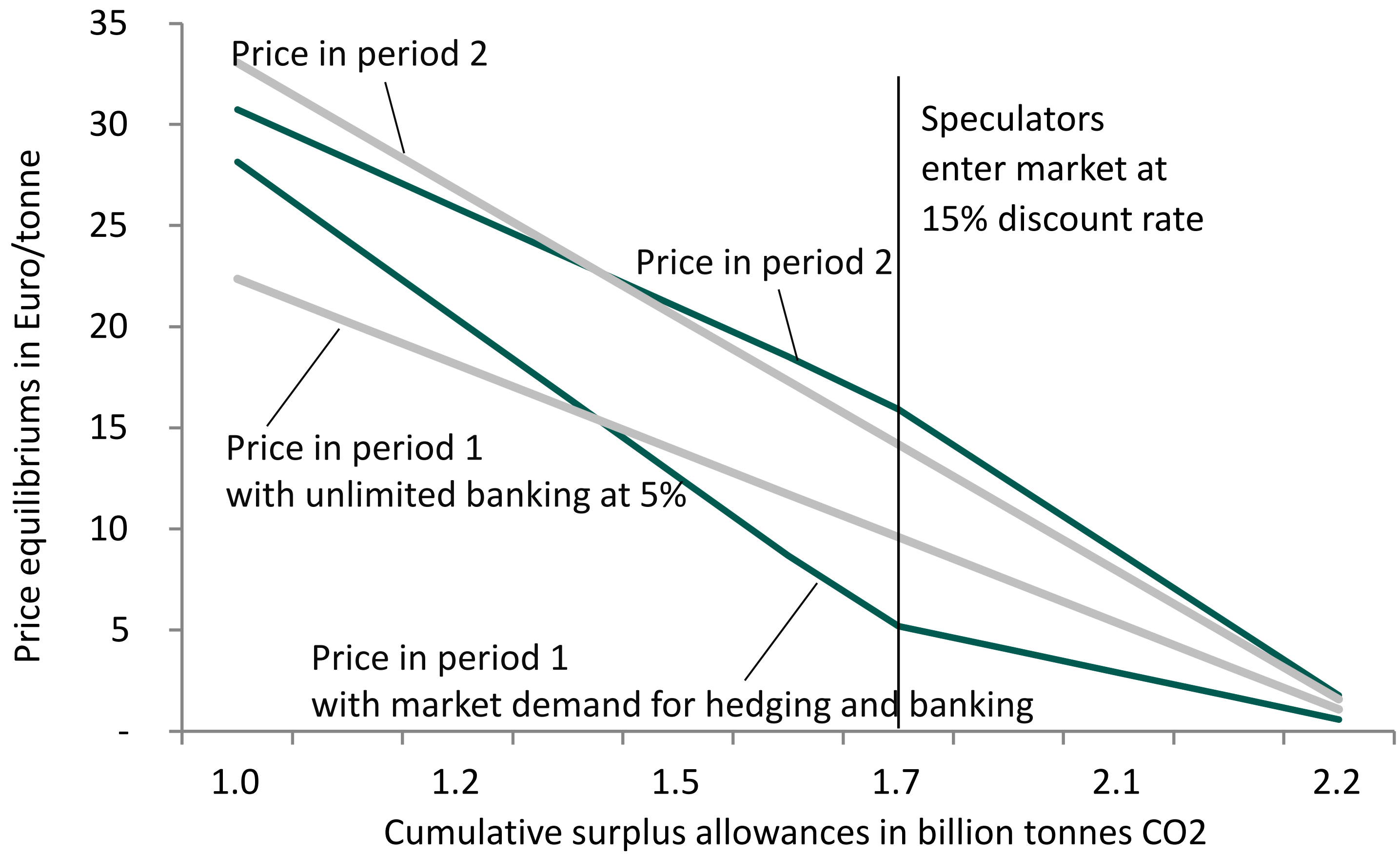
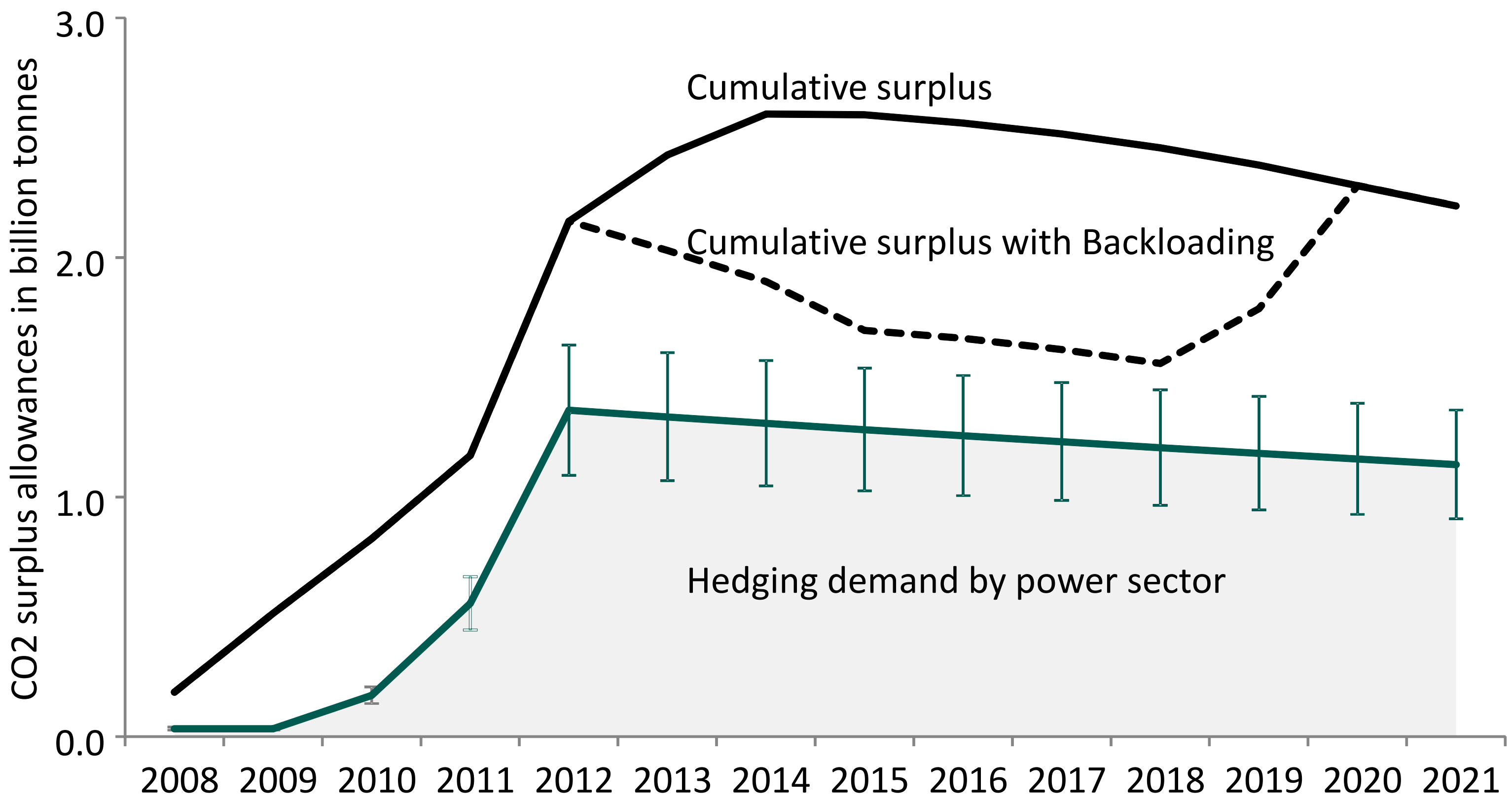
Gap between today's price and price expectations widens with increasing surplus



Backloading 0.9 bn tonnes CO2 shifts surplus closer to hedging corridor



7 Conclusions

- Surplus in EU ETS accumulated since 2008 and is estimated to grow to grow further
- CO2 hedging model: captures hedging schedule and flexibility by power sector to adjust CO2 contracting to price expectations. E.g. CO_2 hedging volume in the corridor of 1.1 to 1.7 billion tonnes for discount rates of 0 to 10%
- Market equilibrium model: With increasing surplus the discrepancy between today's price and price expectations widens
- Surplus of allowances in the EU ETS needs to be reduced to a level corresponding to hedging demand

Thank you for your attention.

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