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Can hedging stabilise carbon markets?

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Outline

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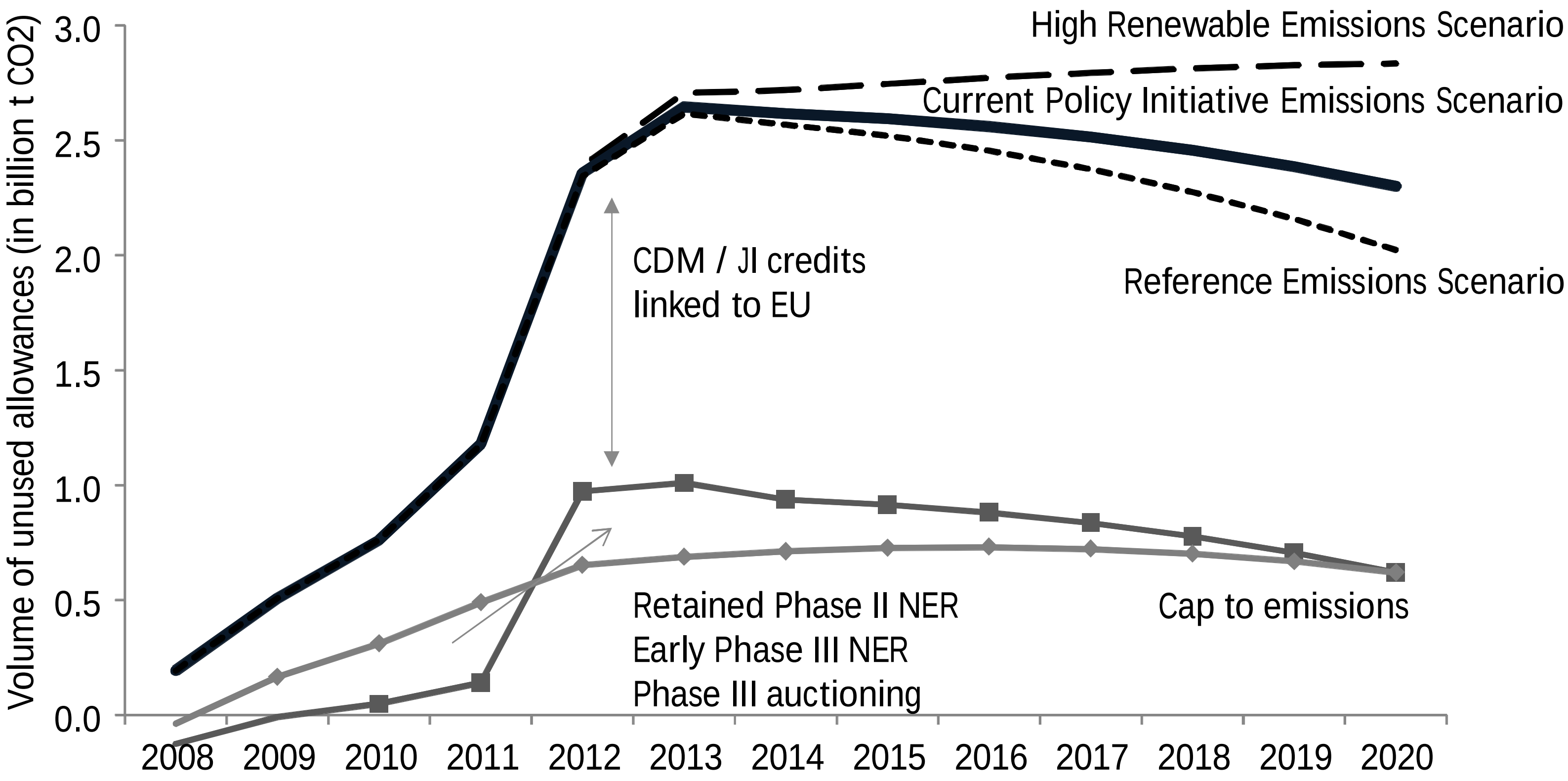
Background on EU Emissions Trading Scheme (1/2)

Cumulative surplus estimated at 2.7 billion t CO2 by 2013



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

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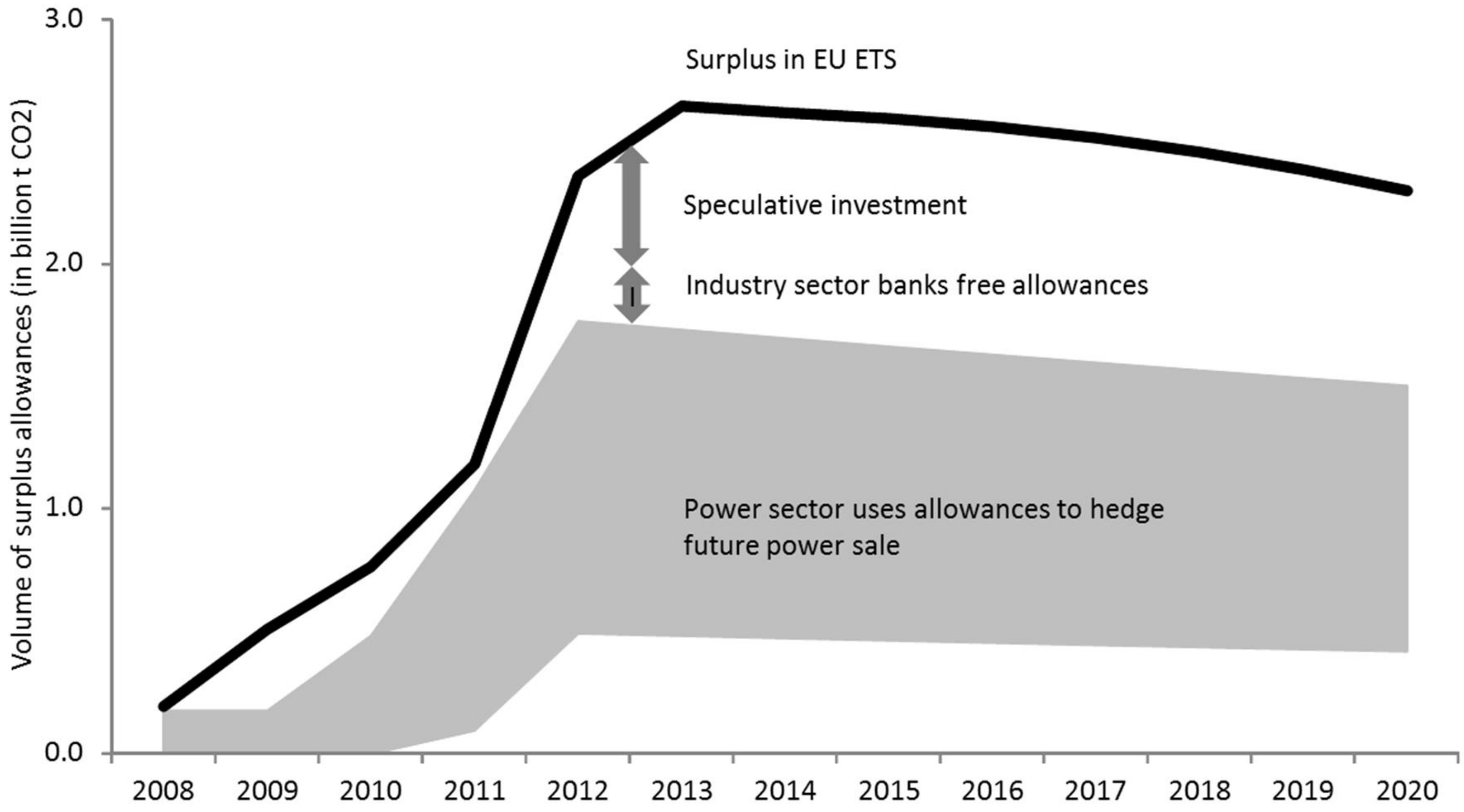
Background on EU Emissions Trading Scheme (2/2)

Gap between surplus and CO2 hedging demand widens in 2012/2013



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

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Research question and approach

Question

Can hedging stabilise carbon markets?

1. How do EU power generators use their flexibility to adjust CO_2 hedging volume?
2. How does CO_2 hedging by power sector interact with CO_2 banking by speculators and CO_2 price dependent emissions levels?

Approach

Analytic model of CO_2 hedgers + model of market equilibrium with CO_2 hedgers, speculators and emitters

Interviews with 13 power generators on CO_2 hedging strategies

Literature

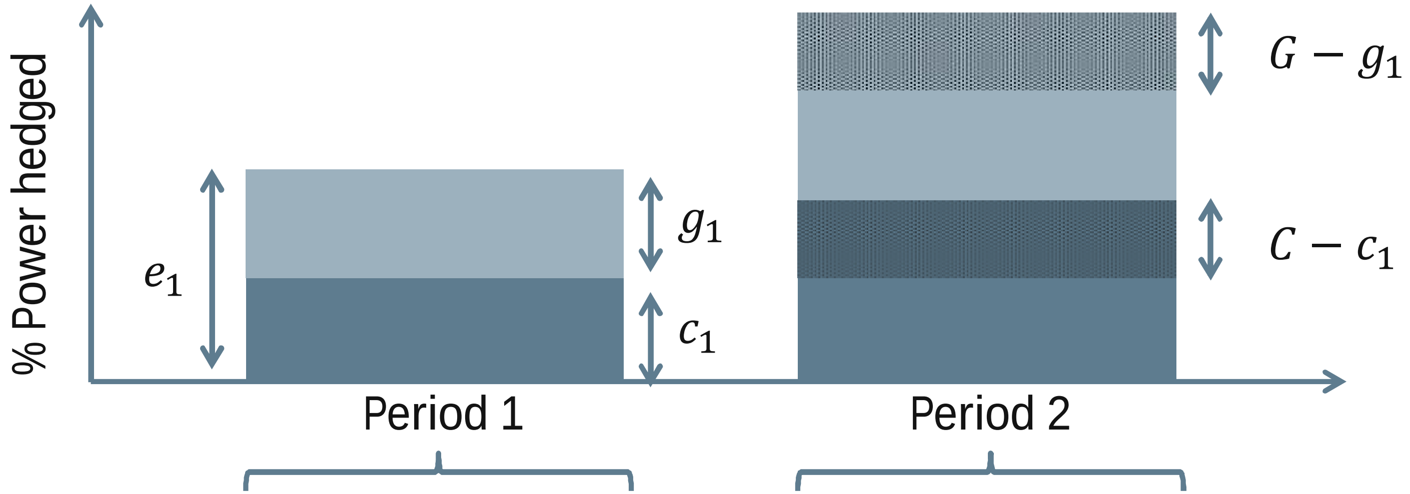
- Banking: Theory and empirical evidence show intertemporal efficiency of banking in emissions trading schemes (Rubins 1996, Ellerman and Montero 2007)

- Models of emissions trading between speculators and emitting firms: Colla, Germain, and Van Steenberghe (2012) find that speculators tend to stabilise prices as speculators increase the risk-bearing capacity of the market

- 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

Model I: Flexibility of CO2 hedging volume (1/5)

2 period model



e_1:	Power contracting	$E - e_1$:	Remaining power
c_1:	Coal contracting	$C - c_1$:	Remaining coal
g_1:	Gas contracting	$G - g_1$:	Remaining gas
i_{CO2}^x:	Carbon intensity	p_2^x:	Forward contract price x
p_1^x:	Forward contract price x ∈ $\{e, c, g, CO2\}$		
$E(p_2^x)$:	Expected price		

Model I: Flexibility of CO2 hedging volume (2/5)

Firm' s objective function:

Deviations of forward prices from expectations

Firm sells power on forward contracts in the years prior to production (period 1):

$$p_1^e * e_1$$

In parallel, firm buys forward contracts for coal, gas and CO2:

$$-p_1^c * c_1 - p_1^g * g_1 - p_1^{CO2} * \left(c_1 * i_{CO2}^c + g_1 * i_{CO2}^g\right)$$

Within the last year (period 2) firm contracts remaining power + fuels to match projected generation:

$$E(p_2^e) * (E - e_1) - E(p_2^c) * (C - c_1) - E\left(p_2^g\right) * (G - g_1)$$
$$-E\left(p_2^{CO2}\right) * (C - c_1) * i_{CO2}^c - E\left(p_2^{CO2}\right) * (G - g_1) * i_{CO2}^g$$

Hedging schedule

Volume and period for which power, fuels and CO_2 is contracted in advance is a corporate risk management strategy decision

$$-\alpha\left((\gamma * C - c_1)^2 + (\gamma * G - g_1)^2\right)$$

γ: Hedging schedule α: Internal transaction cost

4 Model I: Flexibility of CO2 hedging volume (3/5)

The power firm chooses the contract volumes of coal and gas to maximise:

$$\max_{c_1,g_1} -\alpha\left((\gamma * C - c_1)^2 + (\gamma * G - g_1)^2\right) - (c_1 + g_1)(\,E(p_2^e) - p_1^e) + (C+G)\,E(p_2^e)$$
$$+ c_1\left(E(p_2^c) - p_1^c + i_{CO2}^c\left(E\left(p_2^{CO2}\right) - p_1^{CO2}\right)\right) - C\,\left(E(p_2^c) + i_{CO2}^c * E\left(p_2^{CO2}\right)\right)$$
$$+ g_1\left(E\left(p_2^g\right) - p_1^g + i_{CO2}^g\left(E\left(p_2^{CO2}\right) - p_1^{CO2}\right)\right) - G\,\left(E\left(p_2^g\right) + i_{CO2}^g * E\left(p_2^{CO2}\right)\right)$$

Subject to constraints:

1. Firm does not hedge more than it can generate $C - c_1 \geq 0\,,\, G - g_1 \geq 0$
2. No open positions in power sales $e_1 - (c_1 + g_1) = 0$
3. Positive hedging volumes $c_1,\, g_1 \geq 0$

CO2 hedging volume

$$H = \gamma * \left(C * i_{CO2}^c + G * i_{CO2}^g\right) + \frac{[i_{CO2}^c]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}\left(E\left(p_2^{CO2}\right) - p_1^{CO2}\right)$$

4 Model I: Parameterisation (4/5)

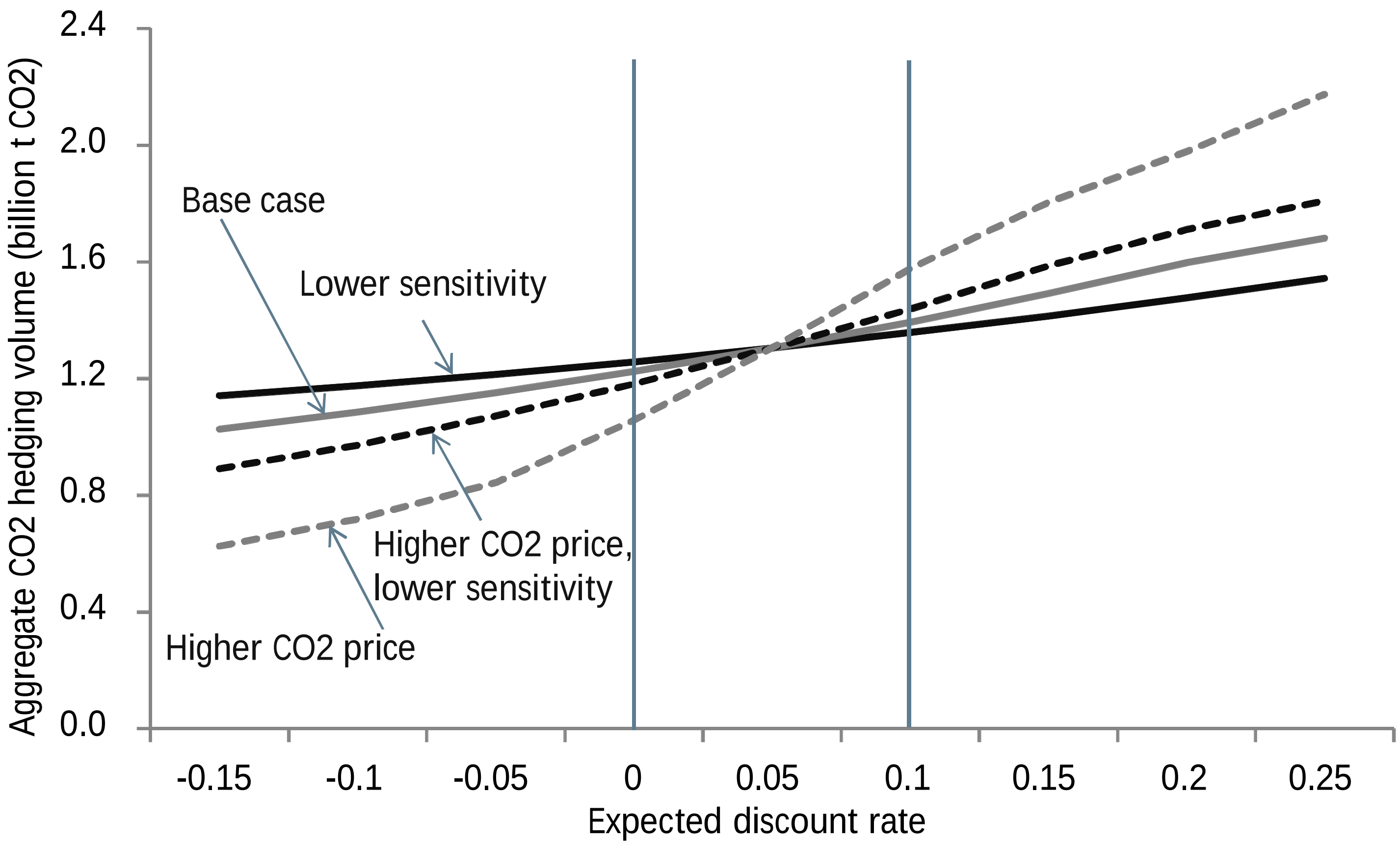
Aggregate hedging schedule **γ** (yearly average in %):

Years	2010	2011	2012	2013
2013	20	46	84	0
2014	0	20	46	84
2015	0	0	20	46
2016	0	0	0	20
Aggregate	20	66	150	150

Internal transaction cost **α** calibrated such that:

– Base case: price of 7.5 €/tCO_2 in period 1 + expected price exceeds forward contract price by Δ1 €/tCO_2
  → 10% CO_2 hedging increase

Flexibility in aggregate CO_2 hedging volume



Lower sensitivity: Δ2 €/tCO2 → Δ 10% CO2 hedging   Higher CO2 price: p1=20 €/tCO2

5 Model II: Market equilibrium with CO2 hedgers, speculators and emitters (1/4)

3 actors in carbon market:

Hedgers

$$Q_1^h = \gamma * \left(C * i_{CO2}^c + G * i_{CO2}^g\right) + \frac{\left[i_{CO2}^c\right]^2 + \left[i_{CO2}^g\right]^2}{2\alpha}\left(E\left(p_2^{CO2}\right) - p_1^{CO2}\right)$$

Hedging schedule — Deviations of CO2 forward prices from expectations

Emitters

$$Q_1^{net\ demand} = \theta_1 + \beta * p_1^{CO2}$$

Surplus — Emission responsiveness

Speculators

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

Speculative responsiveness — Required rate of return

Equilibrium in period 1:

$$\boldsymbol{Q_1^{net\ demand} - Q_1^h - Q_1^s = 0}$$

Equilibrium in period 2:

$$\boldsymbol{Q_2^{net\ demand} + Q_1^h + Q_1^s = 0}$$

5 Model II: Market equilibrium with CO2 hedgers, speculators and emitters (2/4)

Equilibrium in the case of no speculative demand

$$E\left(p_2^{CO2}\right) = \frac{-\theta_2 * \beta - (\theta_1 + \theta_2)\frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha} - \gamma * \beta\left(C * i_{CO2}^c + G * i_{CO2}^g\right)}{\left(\beta + \frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha}\right)^2 - \left(\frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha}\right)^2}$$

$$p_1^{CO2} = \frac{-\theta_1 + \gamma\left(C * i_{CO2}^c + G * i_{CO2}^g\right)}{\beta + \frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha}} + \frac{\left(-\theta_2 * \beta - (\theta_1 + \theta_2)\frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha} - \gamma * \beta\left(C * i_{CO2}^c + G * i_{CO2}^g\right)\right)\left(\frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha}\right)}{\left(\left(\beta + \frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha}\right)^2 - \left(\frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha}\right)^2\right)\left(\beta + \frac{[i_{CO2}^c]^2 + [i_{CO2}^g]^2}{2\alpha}\right)}$$

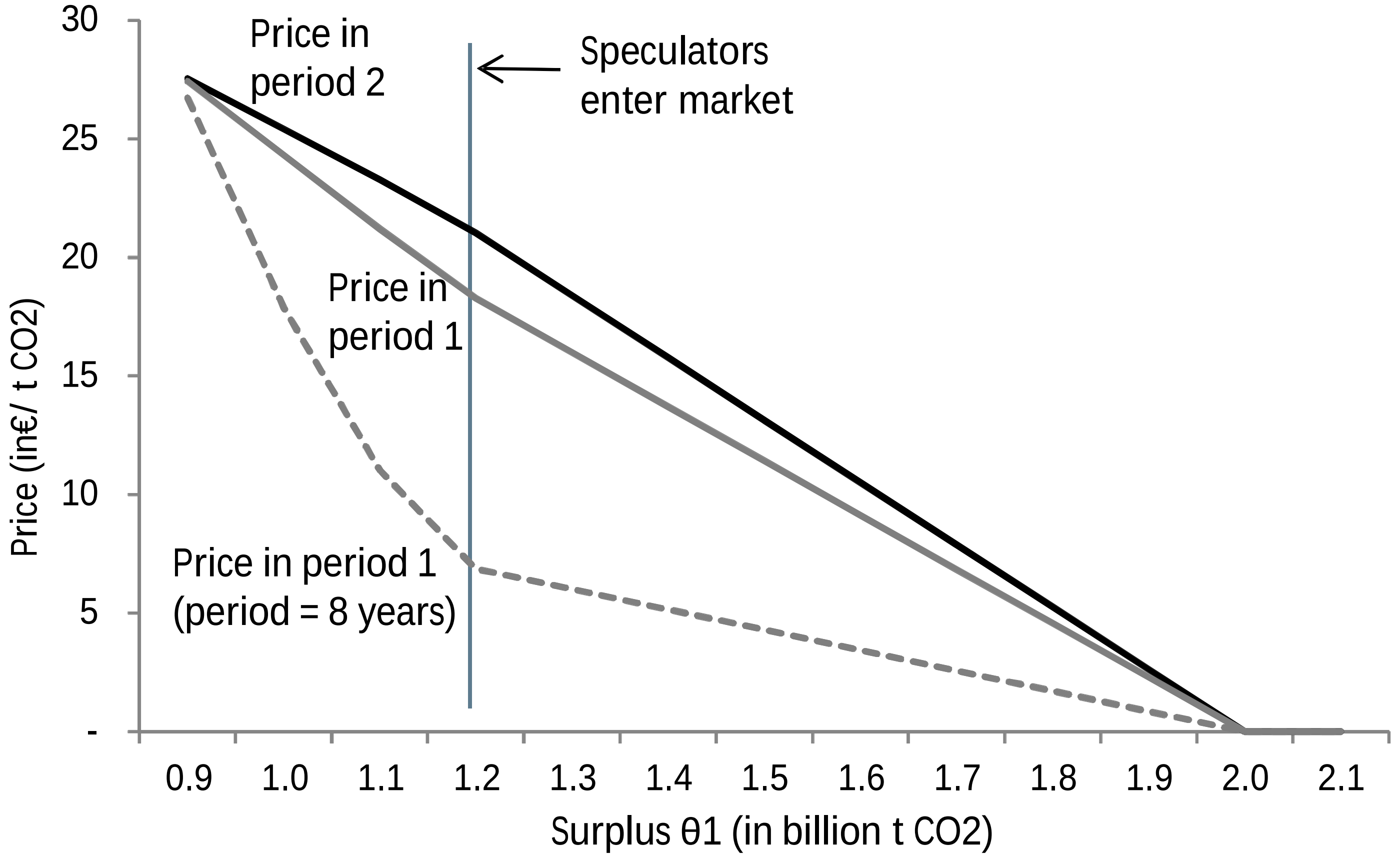
Equilibrium in the case of speculative demand (For $\varphi \rightarrow \infty$, then $\frac{E(p_2^{CO2}) - p_1^{CO2}}{p_1^{CO2}} = \delta_{CO2}^s$)

$$E\left(p_2^{CO2}\right)^* = \frac{-(\theta_1 + \theta_2)(1 + \delta_{CO2}^s)}{\beta(2 + \delta_{CO2}^s)}$$

$$p_1^{CO2^*} = \frac{-(\theta_1 + \theta_2)}{\beta(2 + \delta_{CO2}^s)}$$

Model II: Quantification (3/4)

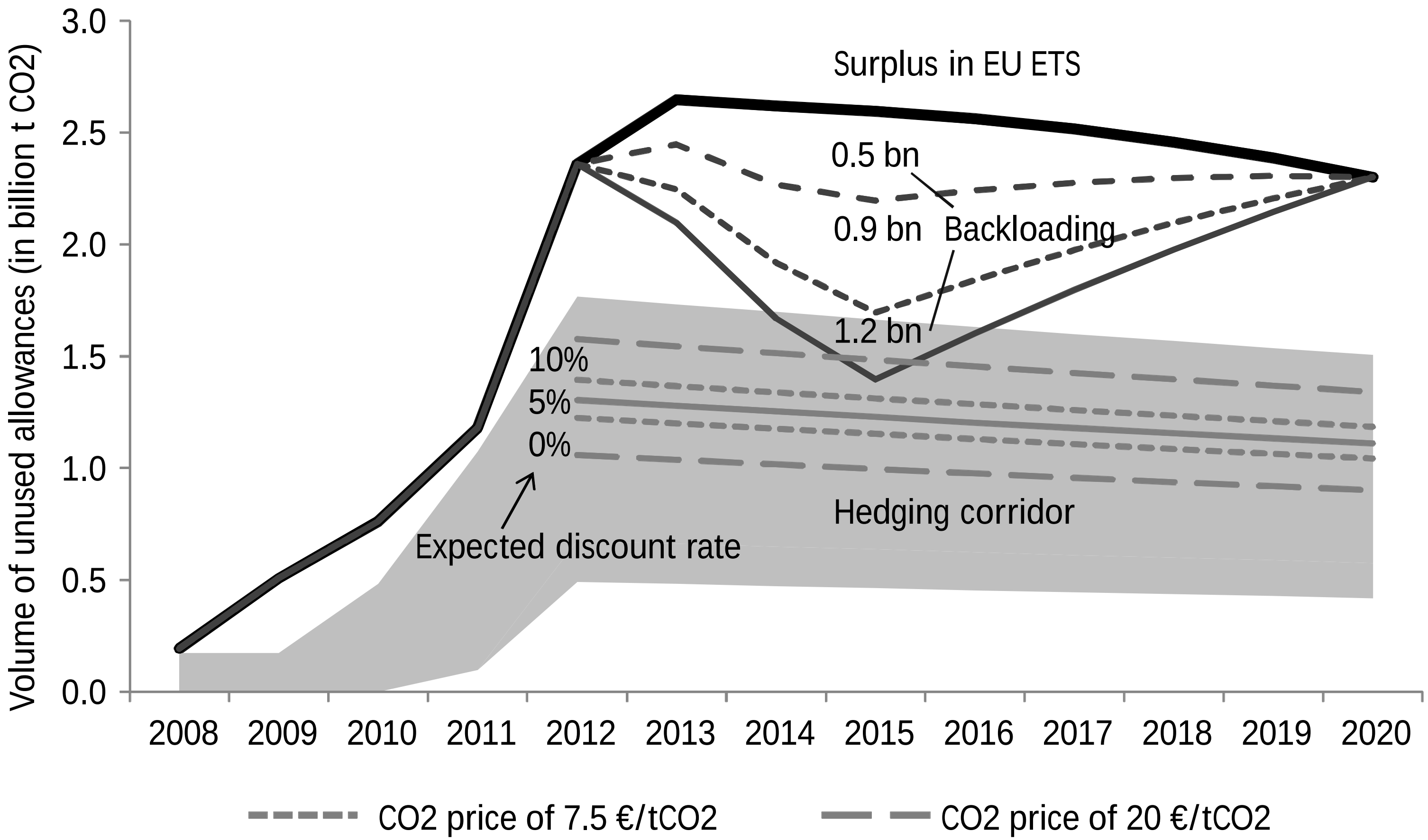
With increasing surplus the discrepancy between today's price and price expectations widens



δ^{S}_{CO2} = 15% $\varphi \rightarrow \infty$ θ_2 = -2.0 bn t CO_2

Model II: Quantification (4/4)

Reducing the surplus in EU ETS by 1.2 billion t CO2 shifts surplus into hedging corridor



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Conclusions

- Surplus in EU ETS accumulated since 2008 and is estimated to grow to 2.7 bn t CO2 by 2013
- CO2 hedging model: captures hedging schedule and flexibility by power sector to adjust CO2 contracting to price expectations. E.g. CO_2 hedging demand in the corridor of 1.1 to 1.6 billion t for discount rates of 0 to 10%.
- Market equilibrium model: helps to explain recent price development
- Surplus of allowances in the EU ETS would need to be reduced to a level that matches the hedging demand of market participants, so as to eliminate the need for large scale banking by speculative investors.

Thank you for your attention.

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