

Can hedging stabilise carbon markets?

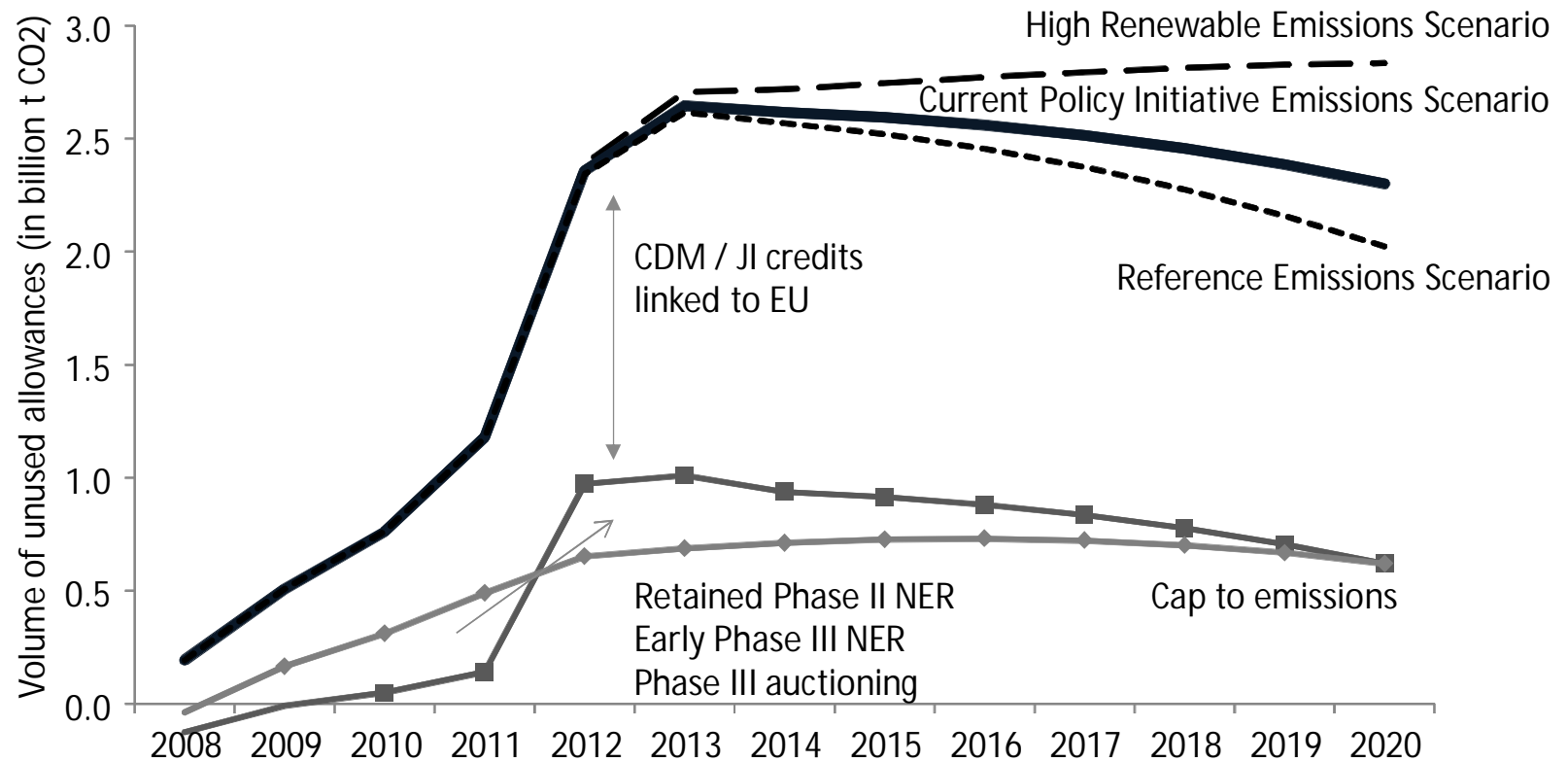
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Outline

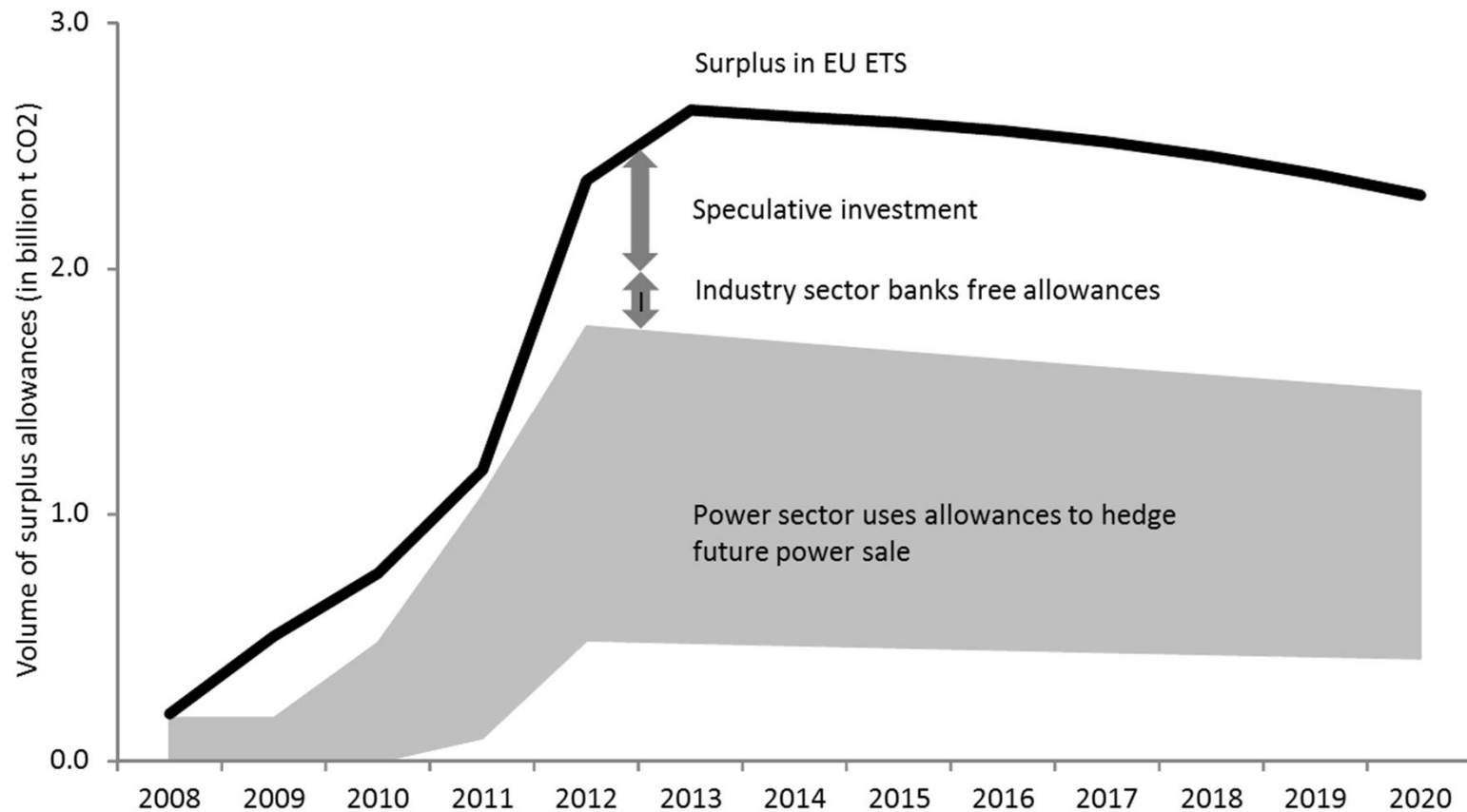
1. Background on EU Emissions Trading Scheme
2. Research question and approach
3. Literature
4. Model I: Flexibility of CO₂ hedging volume
5. Model II: Market equilibrium with CO₂ hedgers, speculators and emitters
6. Conclusions

Cumulative surplus estimated at 2.7 billion t CO₂ by 2013



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

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



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

Question

Can hedging stabilise carbon markets?

1. How do EU power generators use their flexibility to adjust CO2 hedging volume?
2. How does CO2 hedging by power sector interact with CO2 banking by speculators and CO2 price dependent emissions levels?

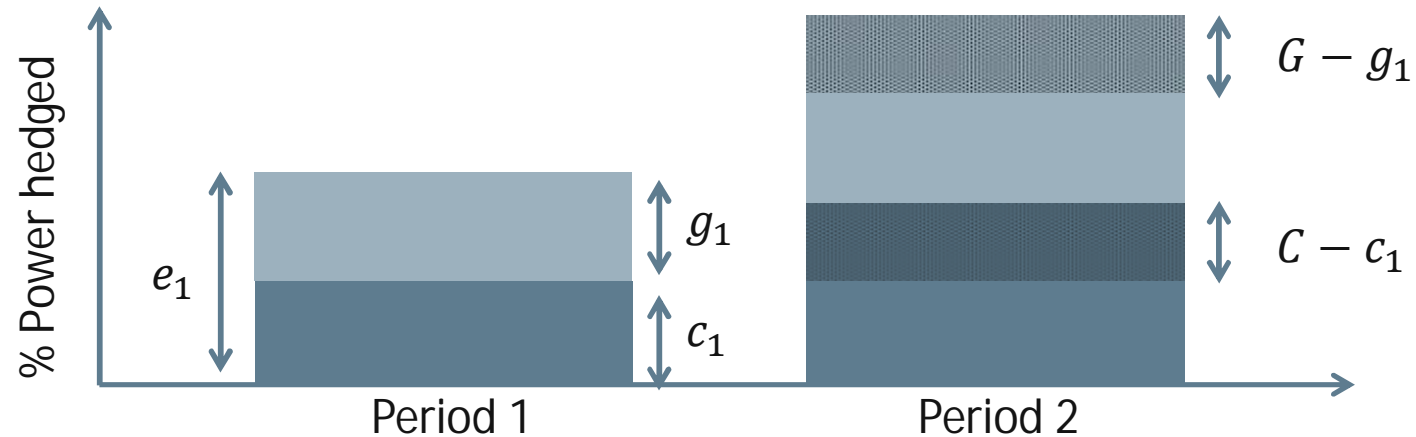
Approach

Analytic model of CO2 hedgers + model of market equilibrium with CO2 hedgers, speculators and emitters

Interviews with 13 power generators on CO2 hedging strategies

- 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

2 period model

 e_1 : Power contracting c_1 : Coal contracting g_1 : Gas contracting $i_{CO_2}^x$: Carbon intensity p_1^x : Forward contract price
 $x \in \{e, c, g, CO_2\}$ $E(p_2^x)$: Expected price $E - e_1$: Remaining power $C - c_1$: Remaining coal $G - g_1$: Remaining gas p_2^x : Forward contract price x

Deviations of forward prices
from expectations

Firm's objective function:

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:

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

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

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

Hedging
schedule

Volume and period for which power, fuels and CO₂ is contracted in advance is a corporate risk management strategy decision

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

γ : Hedging schedule α : Internal transaction cost

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

$$\begin{aligned} \max_{c_1, g_1} & -\alpha((\gamma * C - c_1)^2 + (\gamma * G - g_1)^2) - (c_1 + g_1)(E(p_2^e) - p_1^e) + (C + G)E(p_2^e) \\ & + c_1(E(p_2^c) - p_1^c + i_{CO_2}^c(E(p_2^{CO_2}) - p_1^{CO_2})) - C(E(p_2^c) + i_{CO_2}^c * E(p_2^{CO_2})) \\ & + g_1(E(p_2^g) - p_1^g + i_{CO_2}^g(E(p_2^{CO_2}) - p_1^{CO_2})) - G(E(p_2^g) + i_{CO_2}^g * E(p_2^{CO_2})) \end{aligned}$$

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

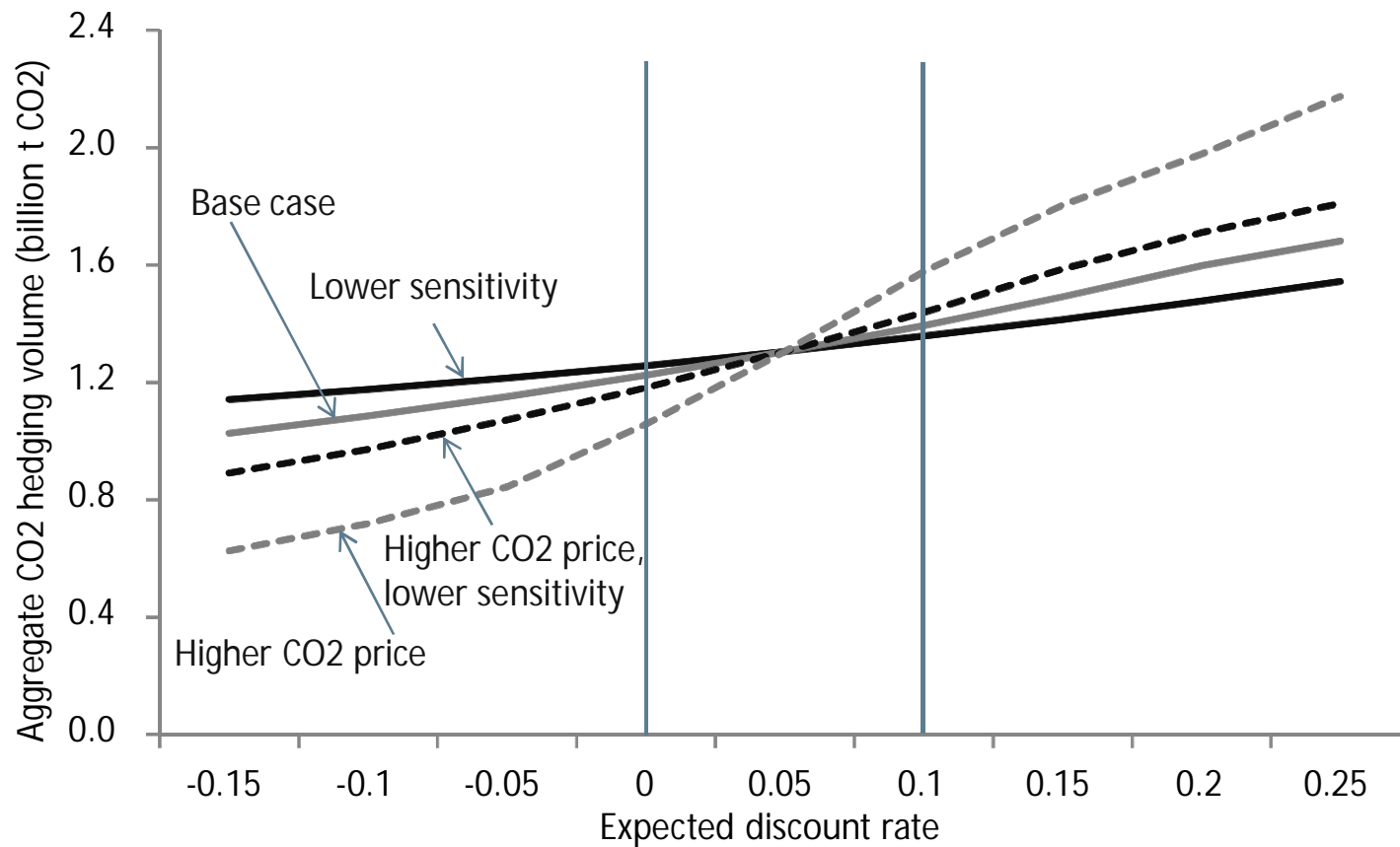
$$H = \gamma * (C * i_{CO_2}^c + G * i_{CO_2}^g) + \frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} (E(p_2^{CO_2}) - p_1^{CO_2})$$

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 €/tCO₂ in period 1 + expected price exceeds forward contract price by $\Delta 1$ €/tCO₂
 → 10% CO₂ hedging increase

Flexibility in aggregate CO₂ hedging volume

Lower sensitivity: $\Delta 2 \text{ €/tCO}_2 \rightarrow \Delta 10\% \text{ CO}_2 \text{ hedging}$

Higher CO₂ price: $p_1 = 20 \text{ €/tCO}_2$

3 actors in carbon market:

Hedgers
$$Q_1^h = \gamma * (C * i_{CO_2}^c + G * i_{CO_2}^g) + \frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} (E(p_2^{CO_2}) - p_1^{CO_2})$$

Hedging schedule
Deviations of CO2 forward prices from expectations

Emitters
$$Q_1^{net\ demand} = \theta_1 + \beta * p_1^{CO_2}$$

Surplus
Emission responsiveness

Speculators
$$Q_1^s = \max\left(\varphi \left(\frac{E(p_2^{CO_2}) - p_1^{CO_2}}{p_1^{CO_2}} - \delta_{CO_2}^s\right), 0\right) = 0$$

Speculative responsiveness
Required rate of return

Equilibrium in period 1:

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

Equilibrium in period 2:

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

Equilibrium in the case of no speculative demand

$$E(p_2^{CO_2}) = \frac{-\theta_2 * \beta \left(-(\theta_1 - \theta_2) \frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} - \gamma * \beta (C * i_{CO_2}^c + G * i_{CO_2}^g) \right)}{\left(\beta + \frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} \right)^2 - \left(\frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} \right)^2}$$

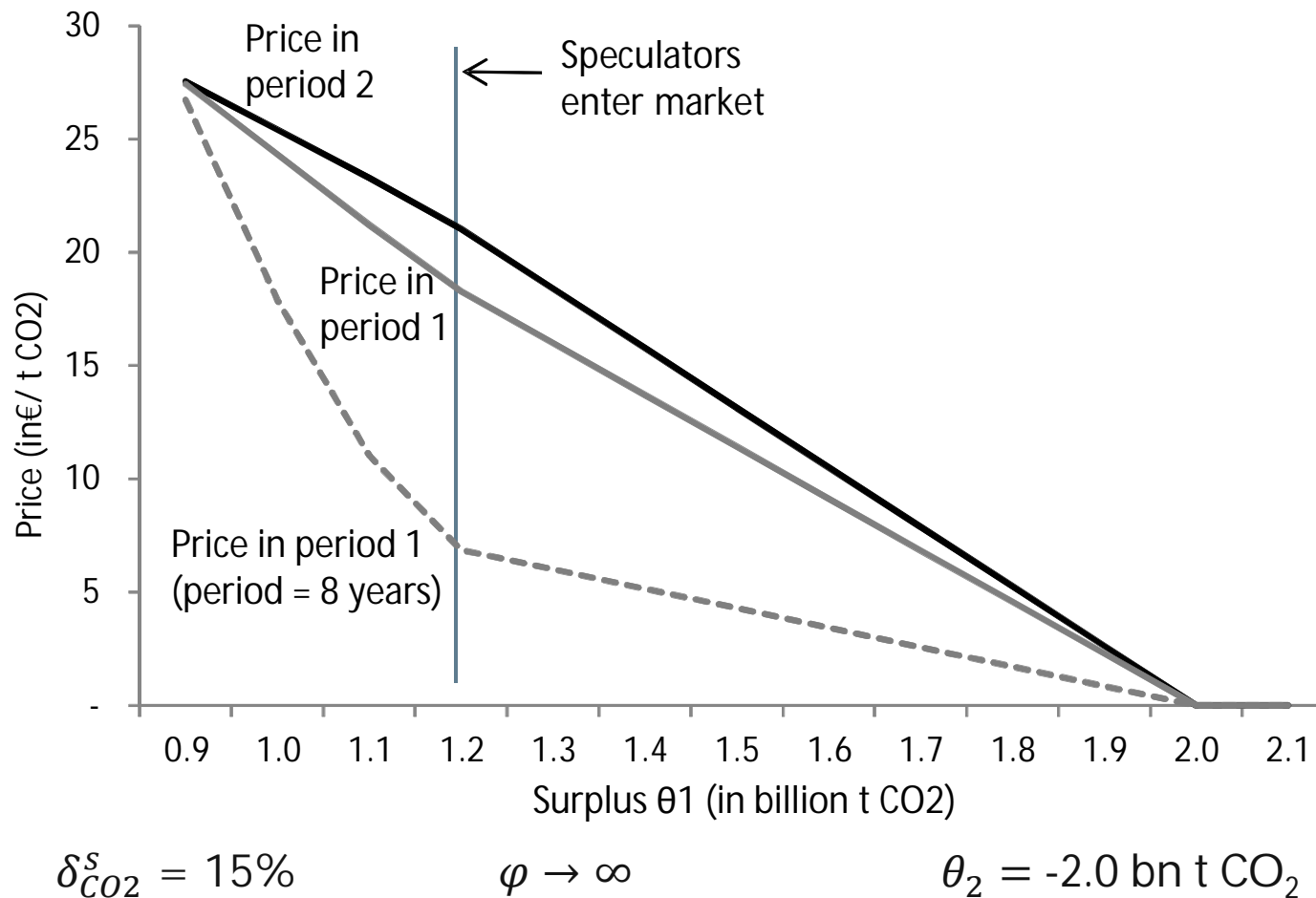
$$p_1^{CO_2} = \frac{-\theta_1 + \gamma(C * i_{CO_2}^c + G * i_{CO_2}^g)}{\beta + \frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha}} + \frac{\left(-\theta_2 * \beta \left(-(\theta_1 + \theta_2) \frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} - \gamma * \beta (C * i_{CO_2}^c + G * i_{CO_2}^g) \right) \right) \left(\frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} \right)}{\left(\left(\beta + \frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} \right)^2 - \left(\frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} \right)^2 \right) \left(\beta + \frac{[i_{CO_2}^c]^2 + [i_{CO_2}^g]^2}{2\alpha} \right)}$$

Equilibrium in the case of speculative demand (For $\varphi \rightarrow \infty$, then $\frac{E(p_2^{CO_2}) - p_1^{CO_2}}{p_1^{CO_2}} = \delta_{CO_2}^S$)

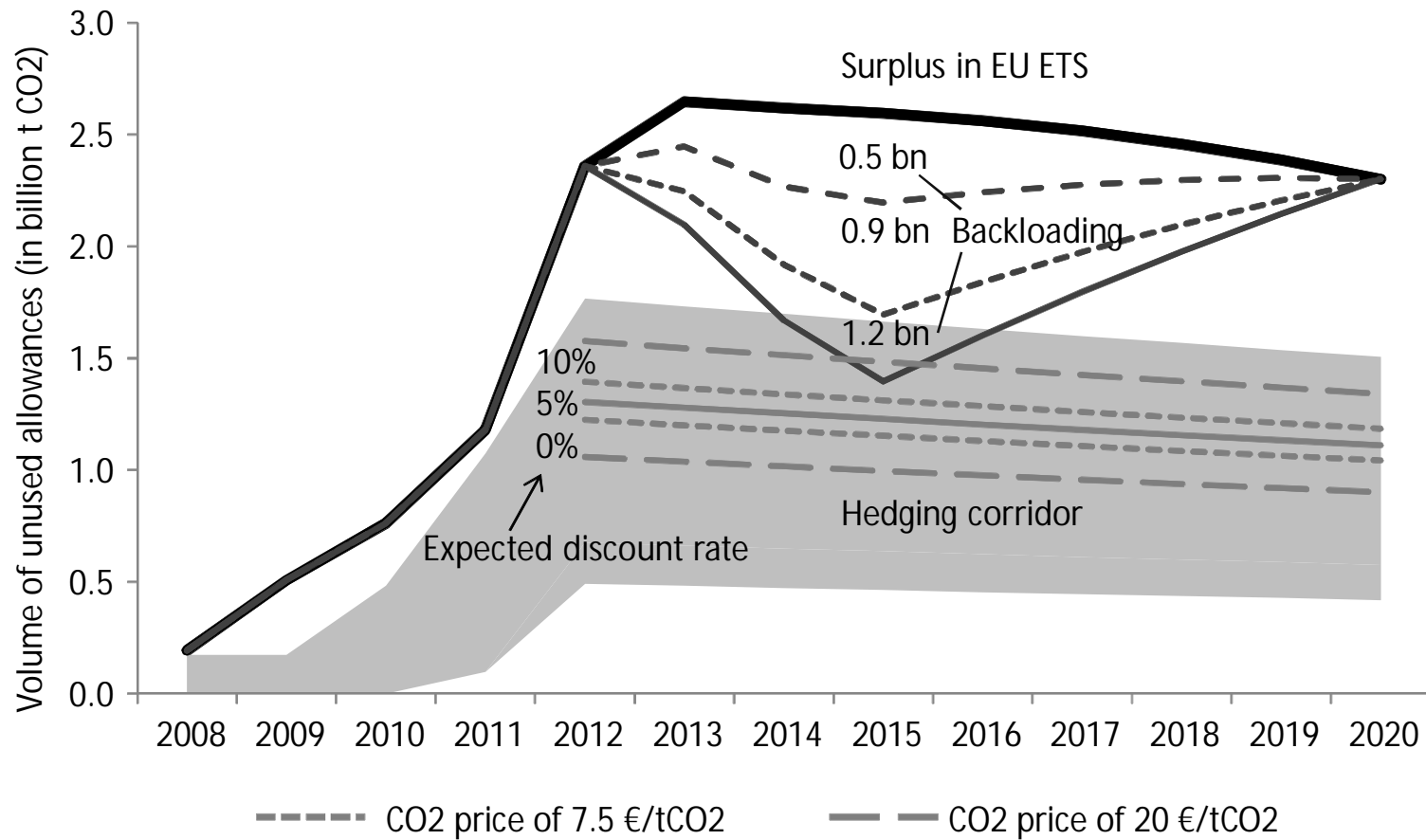
$$E(p_2^{CO_2})^* = \frac{-(\theta_1 + \theta_2)(1 + \delta_{CO_2}^S)}{\beta(2 + \delta_{CO_2}^S)}$$

$$p_1^{CO_2*} = \frac{-(\theta_1 + \theta_2)}{\beta(2 + \delta_{CO_2}^S)}$$

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



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



- 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. CO₂ 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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