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Environmental Assessment

Fachbereich 2 Informatik und Ingenieurwissenschaften

Minimizing deviations

- If the variance for an intensity-based emission cap is lower than for an absolute emission cap, we receive

$$
\begin{aligned}
& var[A^I] < var[A^A] \\
\Rightarrow & e'^2 var[Y] < 2e' cov[Y, E^*] && (1) \\
\Leftrightarrow & \frac{\nu[Y]}{\nu[E^*]\rho[Y, E^*]} \frac{E'}{E[E^*]} < 2 && (2) \\
\Rightarrow & \xi \frac{E'}{E[E^*]} < 2 && (3)
\end{aligned}
$$

- approach follows Sue Wing *et al.* (2009)

Minimizing deviations – exercise

Assume the expectation value approximately corresponds to the ten year average with a time lap of three years.

- Use the data for the German electricity market to calculate ξ for the years 2007 until 2024
- Illustrate your results in an appropriate diagram.
- What do you think about the approximation?

EUA price development

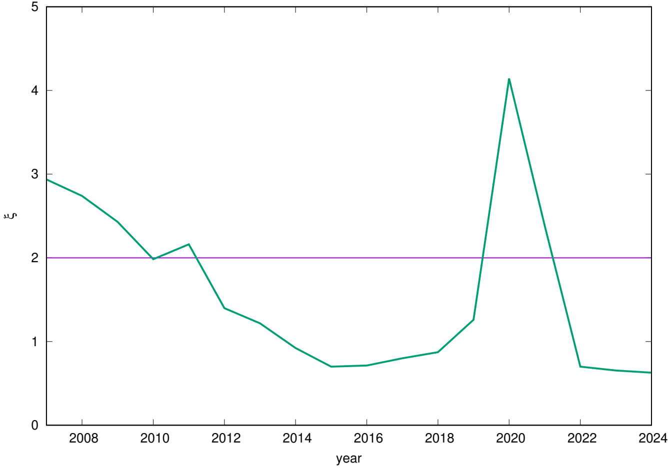

Figure: Development of ξ between 2007 and 2024 according to Sue Wing *et al.* (2009) but with a time lag of three instead of five years. Own illustration.

EUA price development

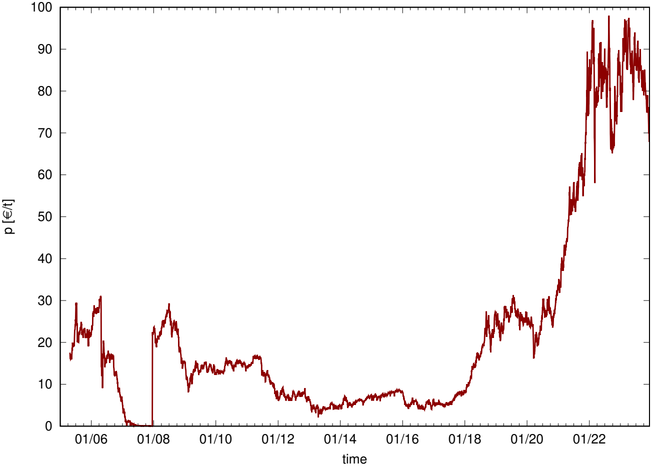

Figure: Development of the allowance price of the EU ETS between April 25, 2005 and December 6, 2023. Own illustration based on investing.com (2023).

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Did the EU ETS induce emission reduction?

- Find literature about the impact of the EU ETS on emission reduction.
- Find a reliable source for CO_2 emissions in the German electricity sector (data not graphs).
- https://ag-energiebilanzen.de/en/data-and-facts/energy-balance-2000-to-2030/
- https://unfccc.int/ghg-inventories-annex-i-parties/2023
- https://ag-energiebilanzen.de/wp-content/uploads/2023/10/STRERZ_Abgabe-09-2023.xlsx

Emission development in Germany

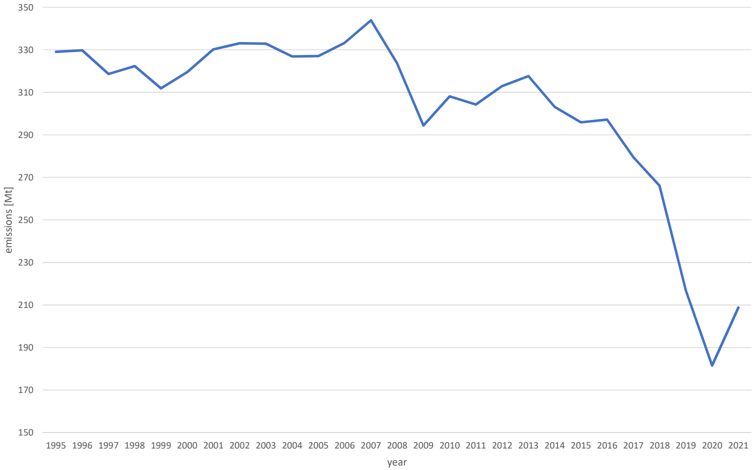

Figure: Development of total emissions in electricity generation from 1995 until 2015 in Germany. Own illustration based on Schäfer (2018).

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Assessment of the EU ETS

- What does affect CO_2 emissions in the electricity sector?
- What is the general problem if we want to evaluate emission abatement induced by the EU ETS?

Assessment of the EU ETS

- Ellerman *et al.* (2010) construct a counterfactual scenario

→ How emissions would have developed if the EU ETS had not been in place?

→ elimination of demand side effects (e.g. economic cycles)

⇒ emission intensities (emissions per electricity output)

→ approach of Ellerman and Buchner (2008); Ellerman *et al.* (2010); Anderson and Di Maria (2011); Egenhofer *et al.* (2011)

→ Ellerman *et al.* (2010) construct a counterfactual scenario for the German electricity sector and calculate emissions abatement in the first trading period

Constructing a counterfactual scenario

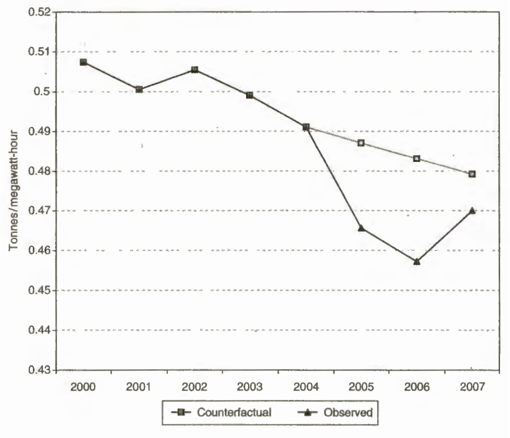

Figure: Development of emission intensity in the German electricity sector from 2000 until 2007 and counterfactual scenario as average of the 2000 – 2004 emissions according to Ellerman *et al.* (2010).

Emission abatement in the 1st trading period

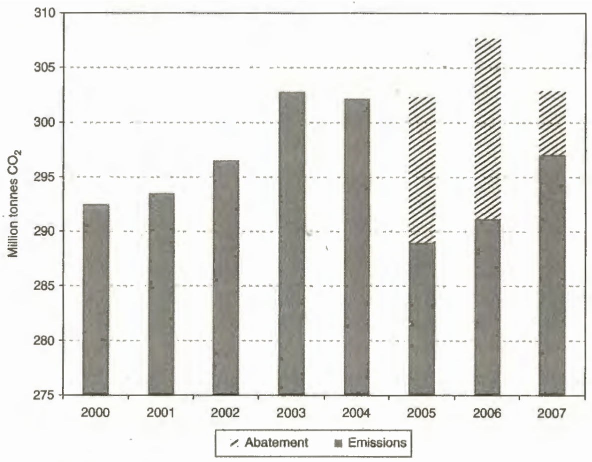

Figure: Emission abatement during the 1st trading period of the EU ETS using the counterfactual intensities developed before; source: (Ellerman *et al.*, 2010).

Evaluation of emission abatement

- Ellerman *et al.* (2010) find a CO_2 abatement amounting to ca. 34.5 Mt within the German electricity sector during the 1st trading period of the EU ETS.

- their analysis faces several problems
- the analysis is based on only 4 values (2000 – 2004) of an uncertain source
- the EU ETS is not the only factor affecting CO_2 emissions in the German electricity sector

→ fuel prices

→ subsidies for RES-based electricity generation

→ In the following we will first set up an alternative approach from 2005 until 2015

Emission development in the German electricity sector

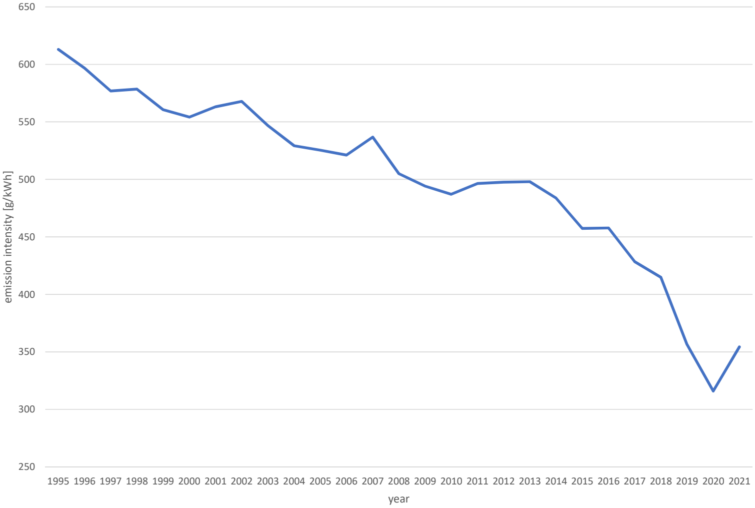

Figure: Development of emission intensity in the German electricity sector from 1995 until 2015. Own illustration based on Schäfer (2018).

Emission intensity development in Germany

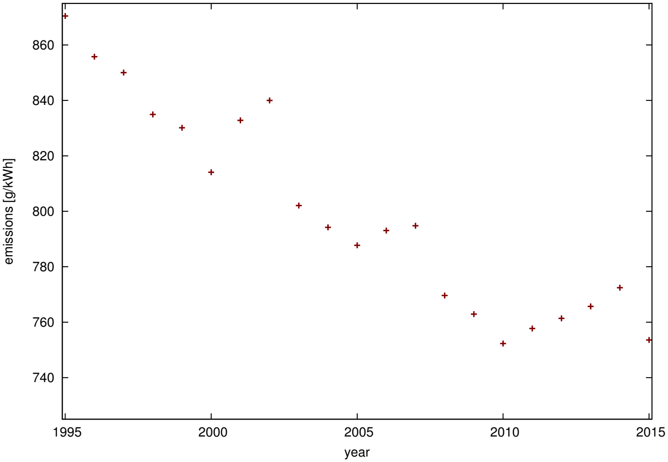

Figure: Development of emission intensity in the German electricity sector within the **sphere of the EU ETS** from 1995 until 2015 according to Schäfer (2018).

Development of fuel prices

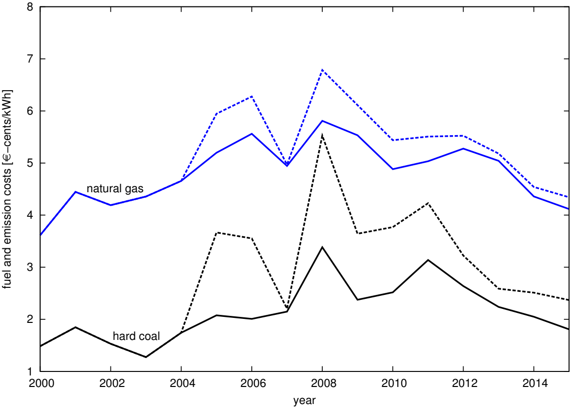

Figure: Development of fuel prices for generation of one kWh electricity based on hard coal respectively gas. The solid lines reflect pure fuel prices $\tilde{p}_{i,coal}$ and $\tilde{p}_{i,gas}$ while the dashed lines also consider emission costs induced by the EU ETS yielding $p_{i,coal}$ and $p_{i,gas}$. Prices also consider changes in the degree of efficiency. Own calculations based on Working Group on Energy Balances (2018,c) and Statistics of the Coal Sector (2018).

Regression of emission intensities

How a reasonable equation considering the time trend, fuel and allowance prices for emission intensities could look like?

$$\ln(e_i) = b + a_t \cdot (i - 2000) + a_p \cdot p_{i,ratio} + \epsilon \tag{4}$$

- b as axis intercept
- ϵ as error term
- $p_{i,ratio}$ corresponds to the price ratio between hard coal and gas $(p_{i,coal}/p_{i,gas})$
- $p_{i,coal}$ and $p_{i,gas}$ consist of pure fuel prices $\tilde{p}_{i,coal}$ and $\tilde{p}_{i,gas}$ plus a respective surcharge $\Delta p_{i,coal}^{ets}$ and $\Delta p_{i,gas}^{ets}$ stemming from the EU ETS

Excursus – coefficient of determination R^2

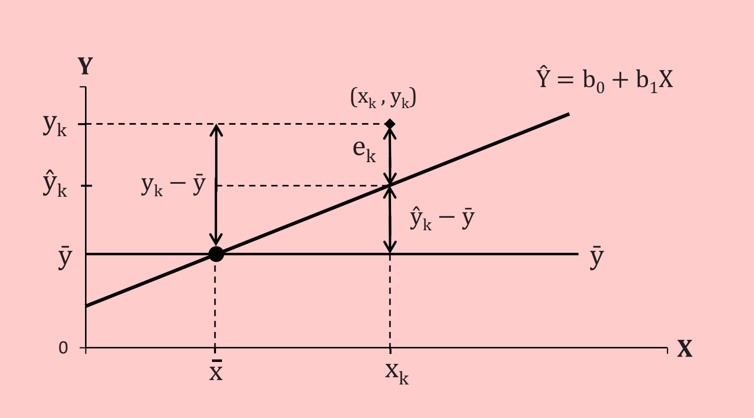

Figure: Decomposition of total deviations from the mean value according to Backhaus *et al.* (2015).

Excursus – coefficient of determination R^2

- We can decompose the total deviation from the mean value

$$\underbrace{y_k - \bar{y}}_{total\ \ deviation} = \underbrace{\hat{y}_k - \bar{y}}_{expl.deviation} + \underbrace{y_k - \hat{y}_k}_{residual}$$

- It can be shown that the following equation holds

$$\underbrace{\sum_{k=1}^{K}(y_k - \bar{y})^2}_{SST} = \underbrace{\sum_{k=1}^{K}(\hat{y}_k - \bar{y})^2}_{SSE} + \underbrace{\sum_{k=1}^{K}(y_k - \hat{y}_k)^2}_{SSR}$$

- This allows to calculate the coefficient of determination

$$R^2 := \frac{SSE}{SST}$$

Regression of emission intensities

	results
R^2	0.842
$\bar{R}^2$	0.818

Table: General statistical analysis of the linear regression with R^2 as coefficient of determination, $\bar{R}^2$ as adjusted coefficient of determination.

	a_t	a_p	b
	-0.0051	-0.0777	6.7440
s	0.0010	0.0310	0.0144
R^2	0.766	0.505	

Table: Statistical analysis of coefficients a_t, a_p, b with s as standard error and R^2 as coefficient of determination resulting from a correlation test for a_i and a_p separately.

ETS assessment – exercise

- Calculate the regression parameters using data for the years 2000 – 2015
- Calibrate the axis intercept so that it equals the average of the years 2000 – 2002 if possible
- Calculate the expectation value of the emission intensities of the counterfactual scenario
- Calculate the expectation value of the absolute emission abatement

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