ZEW

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

The Effect of Electricity Taxation on the German Manufacturing Industry: a Regression Discontinuity Approach.

6th AWEEE: Frontiers in the Economics of Energy Efficiency

June 25, 2014

Benjamin J. Lutz, Centre for European Economic Research (ZEW), Germany

Co-authored with Florens S. Flues, Organisation for Economic Co-operation and Development (OECD), France

Executive Summary

- Quasi-experimental study: Did the German electricity tax have a **_causal impact_** on economic and environmental performance of firms from the manufacturing industry?

- Outcome variables: turnover, turnover abroad, employment, investments, electricity intensity

- The electricity tax is a function of electricity use. **_Discontinuities in the tax function create local random experiments_** that enable us to identify the causal impact

- The empirical analysis is based on official plant- and firm-level census data gathered by the German Federal Statistical Office

- Results: **_The electricity tax did not have a statistically significant causal impact on regulated firms_**

Motivation

- Ambitious climate policy targets in Germany for 2020: need for **_effective_** and **_efficient_** instruments to foster energy efficiency improvements

- Manufacturing industry **_large consumer of electricity_** and of **_high economic importance_**
  - In 2012, the manufacturing industry (incl. mining and quarrying) accounted for 28.9% of Germany's final energy consumption and 43.5% of the total electricity consumption (AGEB 2013)
  - In 2012, the manufacturing industry (incl. mining and quarrying) generated 26.0% of gross value added (Destatis 2013)

- **_Gap in the empirical literature_**: There is only scarce empirical literature on the causal impact of market-based environmental regulation (Fowlie et al., 2012; Martin et al., 2014; Petrick and Wagner, 2014)

Identification Strategy

- The marginal tax rate is a deterministic and discontinuous function of the electricity use
  - The tax reduction scheme creates local random experiments at the thresholds

- Development of the electricity tax scheme over time

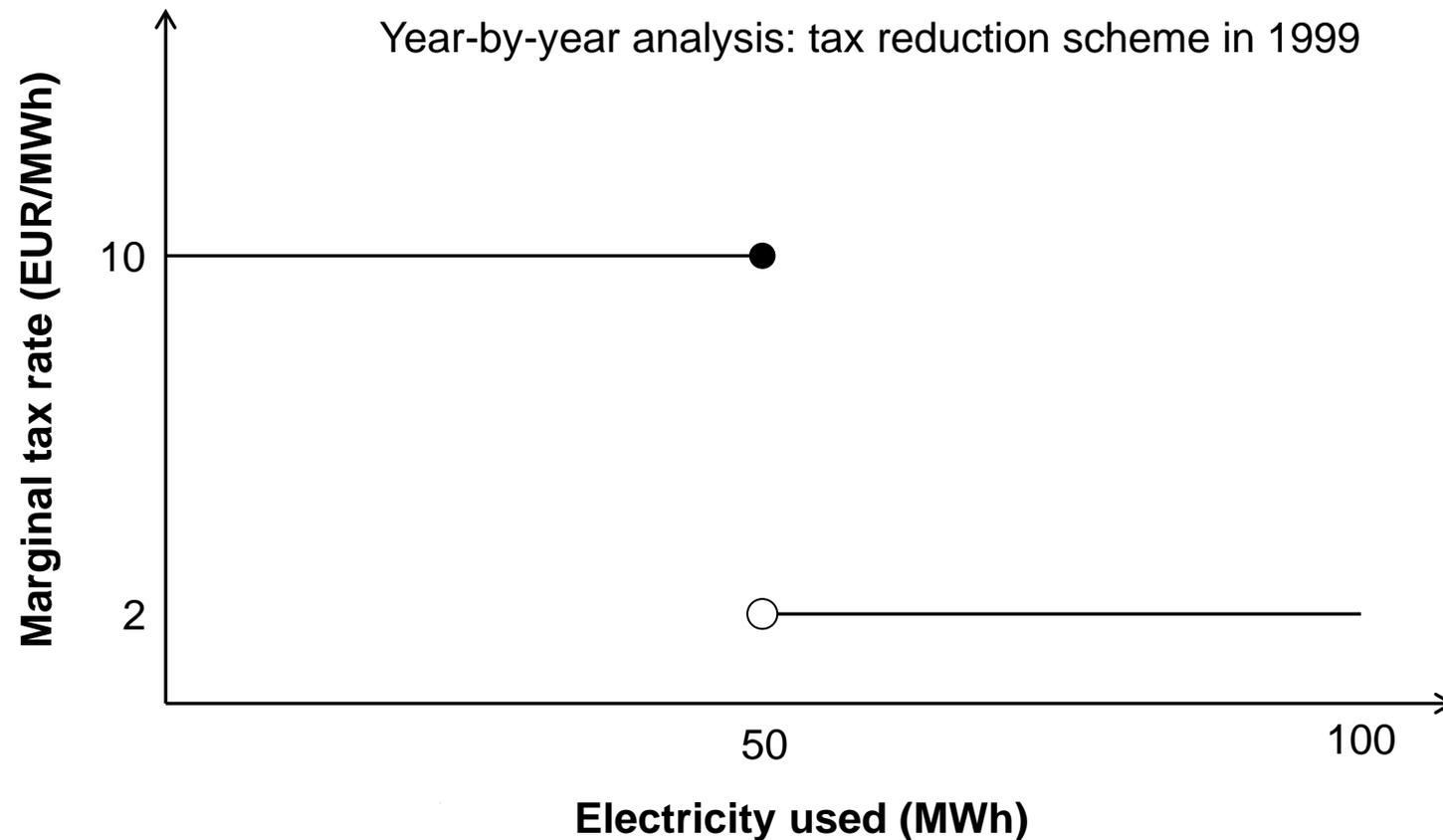| Electricity use threshold	Marginal electricity tax rate in EUR per MWh						
	Until 1999	1999	2000	2001	2002	2003	Until 2010
below 25 MWh	0	10	12.5	15	17.9	20.5	20.5
above 25 MWh	0	10	12.5	15	17.9	12.3	12.3
above 28.6 MWh	0	10	12.5	15	3.6	12.3	12.3
above 33 MWh	0	10	12.5	3	3.6	12.3	12.3
above 40 MWh	0	10	2.5	3	3.6	12.3	12.3
above 50 MWh	0	2	2.5	3	3.6	12.3	12.3

Identification Strategy

- The marginal tax rate is a deterministic and discontinuous function of the electricity use
    - The tax reduction scheme creates local random experiments at the thresholds

- Development of the electricity tax scheme over time

Electricity use threshold	Marginal electricity tax rate in EUR per MWh						
	Until 1999	1999	2000	2001	2002	2003	Until 2010
below 25 MWh	0	10	12.5	15	17.9	20.5	20.5
above 25 MWh	0	10	12.5	15	17.9	12.3	12.3
above 28.6 MWh	0	10	12.5	15	3.6	12.3	12.3
above 33 MWh	0	10	12.5	3	3.6	12.3	12.3
above 40 MWh	0	10	2.5	3	3.6	12.3	12.3
above 50 MWh	0	2	2.5	3	3.6	12.3	12.3

Identification Strategy

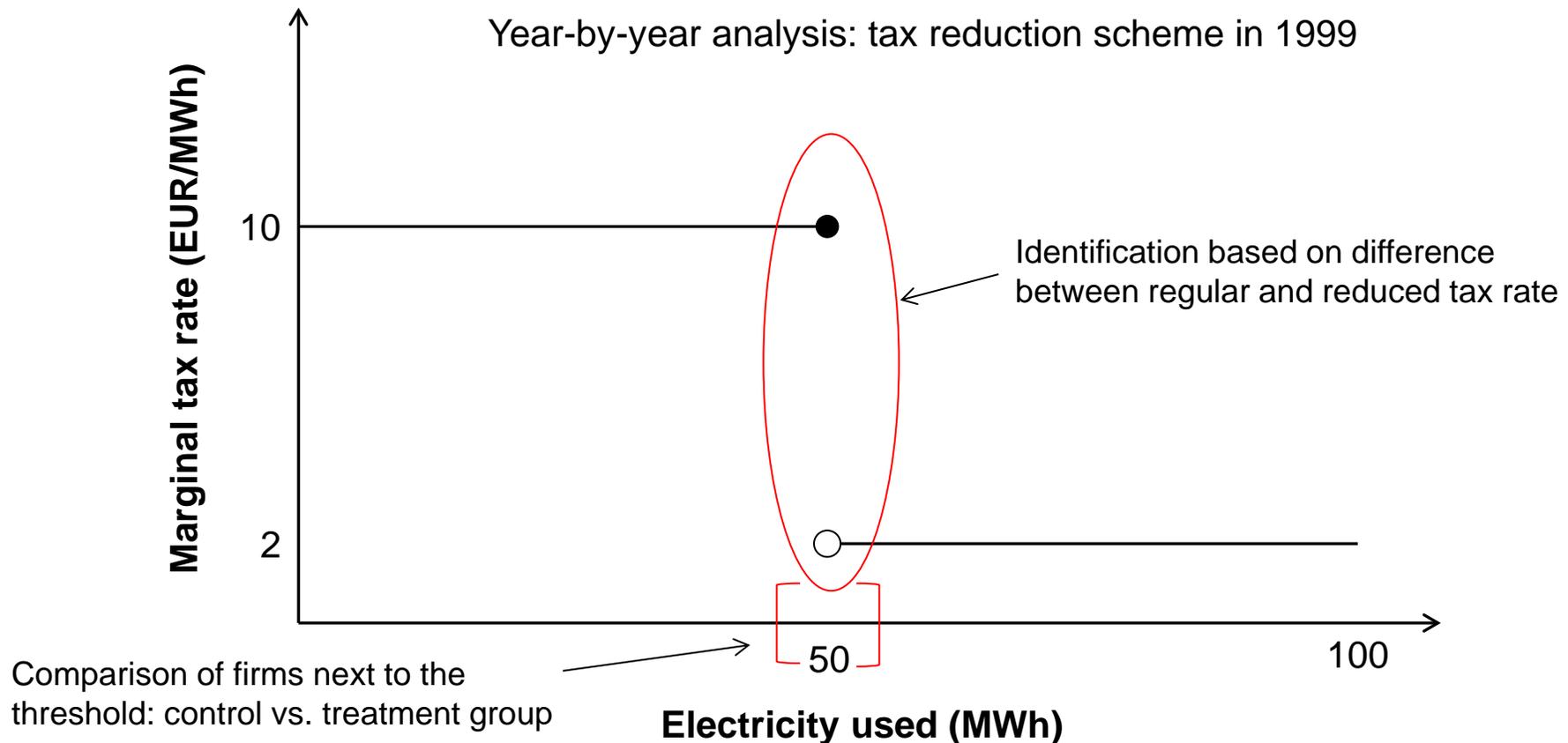- Regression Discontinuity Design: Local Treatment Effect

Year-by-year analysis: tax reduction scheme in 1999

Identification Strategy

- Regression Discontinuity Design: Local Treatment Effect

Year-by-year analysis: tax reduction scheme in 1999

Identification based on difference between regular and reduced tax rate

(y-axis) Marginal tax rate (EUR/MWh): 10, 2

(x-axis) Electricity used (MWh): 50, 100

Identification Strategy

- Regression Discontinuity Design: Local Treatment Effect

Year-by-year analysis: tax reduction scheme in 1999

Identification based on difference between regular and reduced tax rate

Comparison of firms next to the threshold: control vs. treatment group

Marginal tax rate (EUR/MWh)

Electricity used (MWh)

Identification Strategy

- Regression Discontinuity Design: Local Treatment Effect

Year-by-year analysis: tax reduction scheme in 1999

Identification based on difference
between regular and reduced tax rate

**Firms of control and treatment group face
different marginal tax rates, i.e. different
marginal costs associated with electricity use**

Marginal tax rate (EUR/MWh)

10

2

50

100

Electricity used (MWh)

Comparison of firms next to the
threshold: control vs. treatment group

Potential Outcome

Positive effect of reduced marginal electricity tax rate on turnover
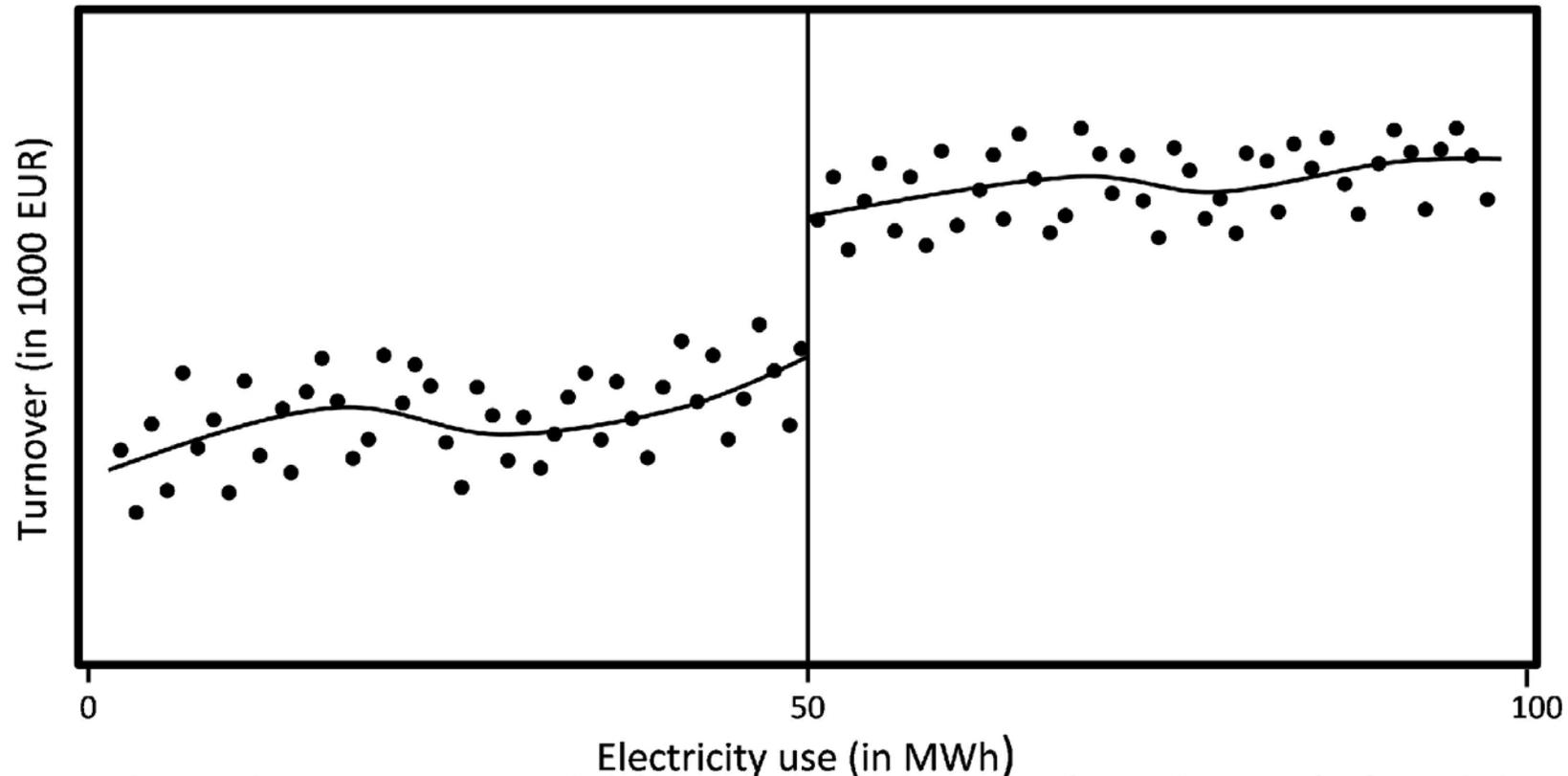
Assumptions: i. outcome variables are continuous functions of electricity use;
ii. firms do not precisely control the forcing variable electricity use

Potential Outcome

No effect of reduced marginal electricity tax rate on turnover
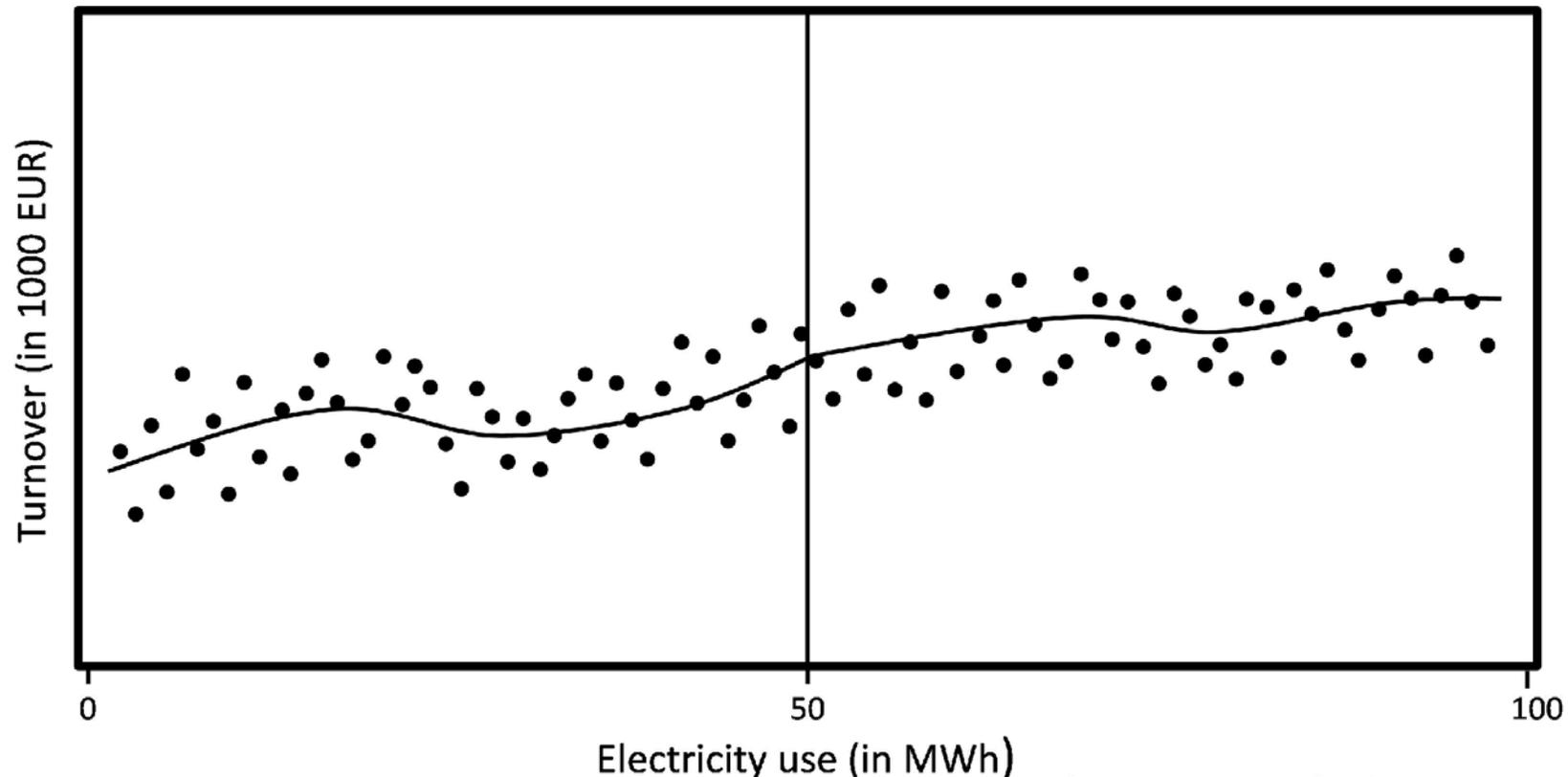
Assumptions: i. outcome variables are continuous functions of electricity use;
ii. firms do not precisely control the forcing variable electricity use

Identifying Assumptions

- Inability to precisely control the assignment variable

- Probability of treatment is a discontinuous function of the assignment variable

- Local continuity restriction

- Stable unit treatment value assumption (SUTVA)

Identifying Assumptions

- Inability to precisely control the assignment variable

- Probability of treatment is a discontinuous function of the assignment variable

- Local continuity restriction

- Stable unit treatment value assumption (SUTVA)

Analytical Framework

- Marginal tax rate t as a function of electricity used X_i

$$t_i = \begin{cases} t_i(0), & \text{if } X_i \leq c \\ t_i(1), & \text{if } X_i > c \end{cases}$$

- Potential outcome framework:

$$Y_i = \begin{cases} Y_i(0), & \text{if } X_i \leq c \\ Y_i(1), & \text{if } X_i > c \end{cases}$$

Analytical Framework

- Sharp discontinuity in the conditional expectation of the outcome given electricity used to unveil an average causal effect of the treatment (Imbens and Lemieux, 2008; Lee and Lemieux, 2010):

$$\lim_{x \downarrow c} E[Y_i \mid X_i = x] - \lim_{x \uparrow c} E[Y_i \mid X_i = x]$$

- Term interpreted as local average treatment effect:

$$\tau = E[Y_i(1) - Y_i(0) \mid X_i = c]$$

Estimation of the Local Treatment Effect

- Non-parametric local polynomial estimator with robust data-driven bandwidth selection and consistent standard errors
  (Calonico et al., 2013, 2014)

- Estimator for the local average treatment effect at the threshold:

$$\hat{\tau} = \hat{\alpha}_{+,p} - \hat{\alpha}_{-,p}$$

- Constants of a weighted polynomial regression

$$Y_i = \begin{cases} \alpha_{-,p} + f_-(X_i - c) + \epsilon_i, & \text{if } X_i \leq c \\ \alpha_{+,p} + f_+(X_i - c) + \epsilon_i, & \text{if } X_i > c \end{cases}$$

- Y_i: Turnover, turnover abroad, number of employees, investments. electricity intensity

Data: German Manufacturing Census

- Econometric analysis exploits official plant- and firm-level census data gathered by the German Federal Statistical Office on an annual basis

- All firms of the manufacturing sector with more than 20 employees are included: participation is mandatory

- Data set covers characteristics, such as performance measures, investments, and energy consumption

- Analysis focusses on the years 1999-2005

Data: Descriptive Statistics

	Mean	St. Dev.	P10	P 50	P90	N
Panel A: 1995						
Turnover (in 1000 EUR)	25,010.07	280,545.50	1,228.51	4,858.56	35,930.73	41,246
Number of Employees	163.63	1,467.75	22	51.5	268.08	41,246
Investments (in 1000 EUR)	1,201.30	12,201.98	0	140.15	1821.49	34,819
Turnover Abroad (in 1000 EUR)	7,210.28	137,665.70	0	82.79	7,501.25	41,246
Electricity Used (in MWh)	4,162.72	59,489.87	34.67	294.90	4,030.619	41,137
Electricity Intensity (in EUR per kWh)	0.1329	0.6958	0.0113	0.0630	0.2825	40,968
Panel B: 2000						
Turnover (in 1000 EUR)	30,567.17	420,230.20	1,317.18	5,204.79	41,738.11	41,776
Number of Employees	152.85	1,302.24	22.17	49.67	255.17	41,776
Investments (in 1000 EUR)	1,342.97	16,605.95	0	137.59	1,872.448	38,670
Turnover Abroad (in 1000 EUR)	11,290.30	260,512.80	0	120.14	10,921.21	41,776
Electricity Used (in MWh)	4,657.95	62,160.88	37.09	311.56	4538.08	41720
Electricity Intensity (in EUR per kWh)	0.1296	0.5663	0.0109	0.0647	0.2772	41,602
Panel C: 2005						
Turnover (in 1000 EUR)	36,518.24	534,968.60	1359.46	5,754.88	48,423.67	40,215
Number of Employees	147.56	1260.47	22.08	49.67	241.92	40,215
Investments (in 1000 EUR)	1,191.88	16,961.96	0	97.58	1,567.83	37,295
Turnover Abroad (in 1000 EUR)	14,905.99	321,597.60	0	292.568	15,408.68	40,215
Electricity Used (in MWh)	5,533.83	64,108.09	57	415.56	5,696.71	38,675
Electricity Intensity (in EUR per kWh)	0.1862	3.5639	0.0136	0.0740	0.2992	38,337

Results: Local Treatment Effects

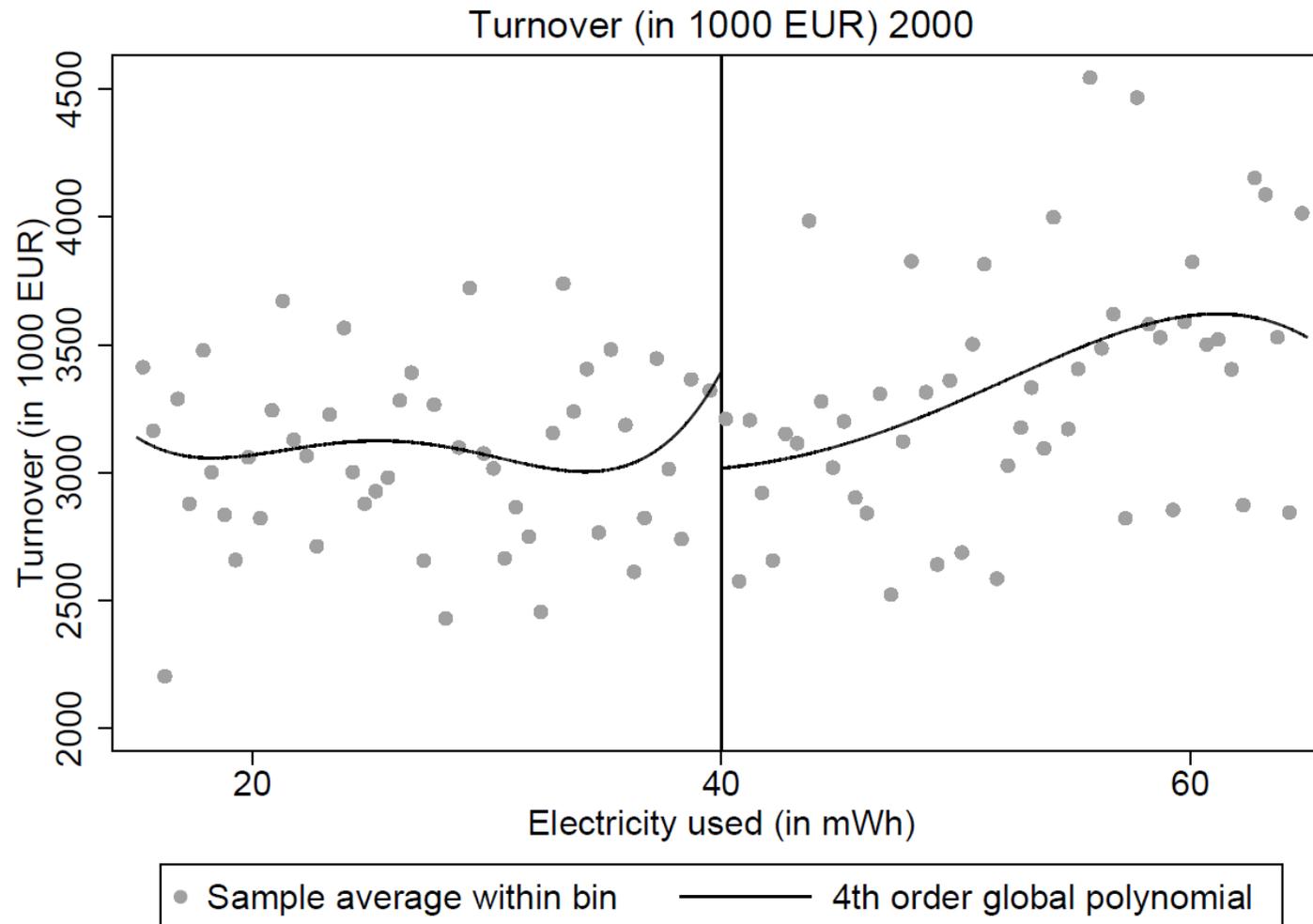|	Tax reduction scheme			Effect of reduced marginal tax rate				
Year	Threshold (MWh)	Full tax rate (EUR/MWh)	Tax reduction (EUR/MWh)	Turnover	Employ-ment	Invest-ments	Turnover abroad	Electricity intensity
1999	50	10	8	225.290 (0.414)	-0.065 (0.859)	-28.089 (0.233)	-83.794 (0.618)	-0.002 (0.350)
2000	40	12.5	10	-264.170 (0.345)	-1.771 (0.333)	16.568 (0.428)	-264.750 (0.137)	0.002 (0.373)
2001	33	15	12	817.670* (0.025)	1.310 (0.498)	-9.090 (0.478)	-278.450 (0.106)	-0.003 (0.126)
2002	28.6	17.9	14.6	-505.130 (0.090)	-0.561 (0.737)	-13.988 (0.610)	33.765 (0.680)	0.001 (0.700)
2003	25	20.5	8.2	318.290 (0.391)	2.334 (0.357)	14.604 (0.403)	-285.130 (0.403)	0.000 (0.800)
2004	25	20.5	8.2	498.150 (0.148)	7.318** (0.004)	6.828 (0.580)	-37.665 (0.9609)	-0.001 (0.341)
2005	25	20.5	8.2	-220.550 (0.623)	4.893* (0.029)	3.845 (0.996)	599.360* (0.035)	0.001 (0.498)

Turnover, investments and turnover abroad are denoted in EUR 1000. P Values in parantheses. ** sign. at 1% level; * sign. at 5 % level

Results: Local Treatment Effects

	Tax reduction scheme			Effect of reduced marginal tax rate				
Year	Threshold (MWh)	Full tax rate (EUR/MWh)	Tax re-duction (EUR/MWh)	Turnover	Employ-ment	Invest-ments	Turnover abroad	Electricity intensity
1999	50	10	8	225.290 (0.414)	-0.065 (0.859)	-28.089 (0.233)	-83.794 (0.618)	-0.002 (0.350)
2000	40	12.5	10	-264.170 (0.345)	-1.771 (0.333)	16.568 (0.428)	-264.750 (0.137)	0.002 (0.373)
2001	33	15	12	817.670* (0.025)	1.310 (0.498)	-9.090 (0.478)	-278.450 (0.106)	-0.003 (0.126)
2002	28.6	17.9	14.6	-505.130 (0.090)	-0.561 (0.737)	-13.988 (0.610)	33.765 (0.680)	0.001 (0.700)
2003	25	20.5	8.2	318.290 (0.391)	2.334 (0.357)	14.604 (0.403)	-285.130 (0.403)	0.000 (0.800)
2004	25	20.5	8.2	498.150 (0.148)	7.318** (0.004)	6.828 (0.580)	-37.665 (0.9609	-0.001 (0.341)
2005	25	20.5	8.2	-220.550 (0.623)	4.893* (0.029)	3.845 (0.996)	599.360* (0.035)	0.001 (0.498)

Turnover, investments and turnover abroad are denoted in EUR 1000. P Values in parantheses. ** sign. at 1% level; * sign. at 5 % level
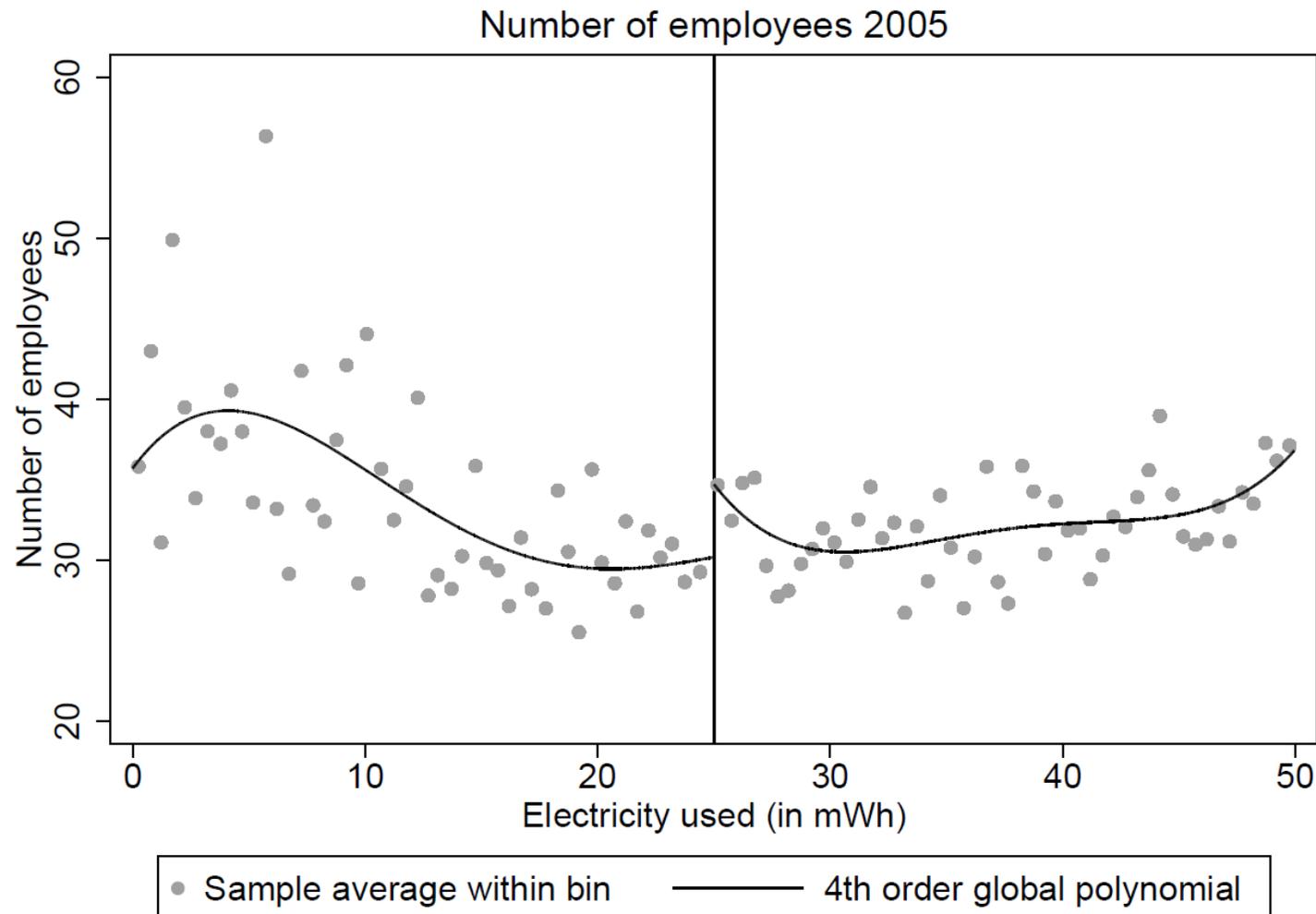
Results: Local Treatment Effects

Year	Tax reduction scheme			Effect of reduced marginal tax rate				
	Threshold (MWh)	Full tax rate (EUR/MWh)	Tax re-duction (EUR/MWh)	Turnover	Employ-ment	Invest-ments	Turnover abroad	Electricity intensity
1999	50	10	8	225.290 (0.414)	-0.065 (0.859)	-28.089 (0.233)	-83.794 (0.618)	-0.002 (0.350)
2000	40	12.5	10	-264.170 (0.345)	-1.771 (0.333)	16.568 (0.428)	-264.750 (0.137)	0.002 (0.373)
2001	33	15	12	817.670* (0.025)	1.310 (0.498)	-9.090 (0.478)	-278.450 (0.106)	-0.003 (0.126)
2002	28.6	17.9	14.6	-505.130 (0.090)	-0.561 (0.737)	-13.988 (0.610)	33.765 (0.680)	0.001 (0.700)
2003	25	20.5	8.2	318.290 (0.391)	2.334 (0.357)	14.604 (0.403)	-285.130 (0.403)	0.000 (0.800)
2004	25	20.5	8.2	498.150 (0.148)	7.318** (0.004)	6.828 (0.580)	-37.665 (0.9609	-0.001 (0.341)
2005	25	20.5	8.2	-220.550 (0.623)	4.893* (0.029)	3.845 (0.996)	599.360* (0.035)	0.001 (0.498)

Turnover, investments and turnover abroad are denoted in EUR 1000. P Values in parantheses. ** sign. at 1% level; * sign. at 5 % level

Results: Graphical Analysis

Turnover (in 1000 EUR) 2000

x-axis: Electricity used (in mWh)
y-axis: Turnover (in 1000 EUR)

Legend: Sample average within bin — 4th order global polynomial

Results: Graphical Analysis

Number of employees 2005

Legend: Sample average within bin ● — 4th order global polynomial

x-axis: Electricity used (in mWh)
y-axis: Number of employees

Conclusion

- No significant causal effect of electricity tax on firms' turnover, turnover abroad, number of employees, investments, electricity intensity

- Other studies on the causal impact of environmental regulation on the manufacturing sector in Europe also show no evidence for adverse effects on competitiveness (Martin et al., 2014; Petrick and Wagner, 2014)

- Elimination of tax reduction scheme would increase revenues for the government without significantly harming firms – additional tax revenues could be used to lower taxes or social security contributions on labor

- To be done:
    - RDD in combination with stochastic frontier analysis

ZEW

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research

Back Up

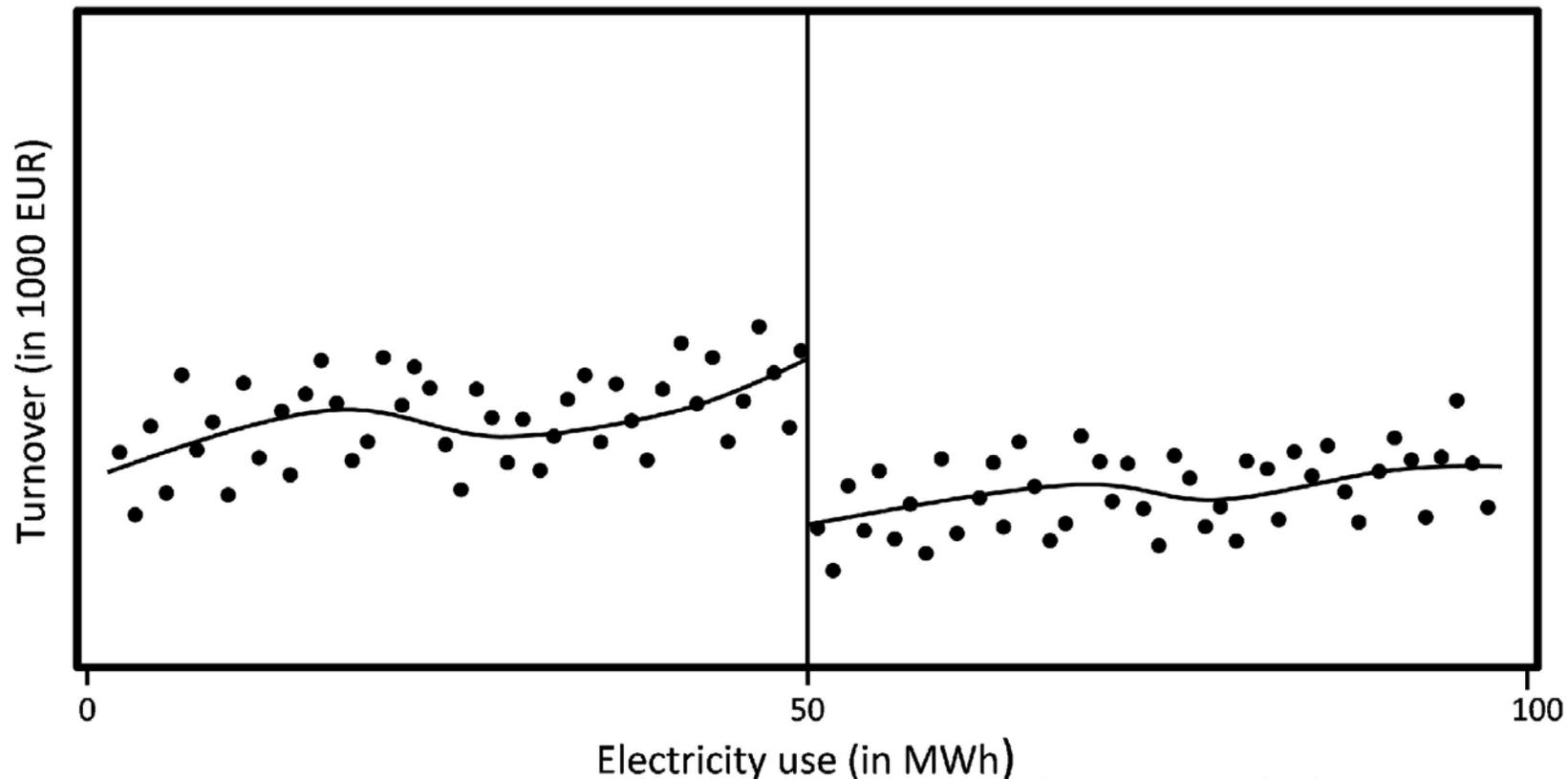# Distribution of the Assignment Variable
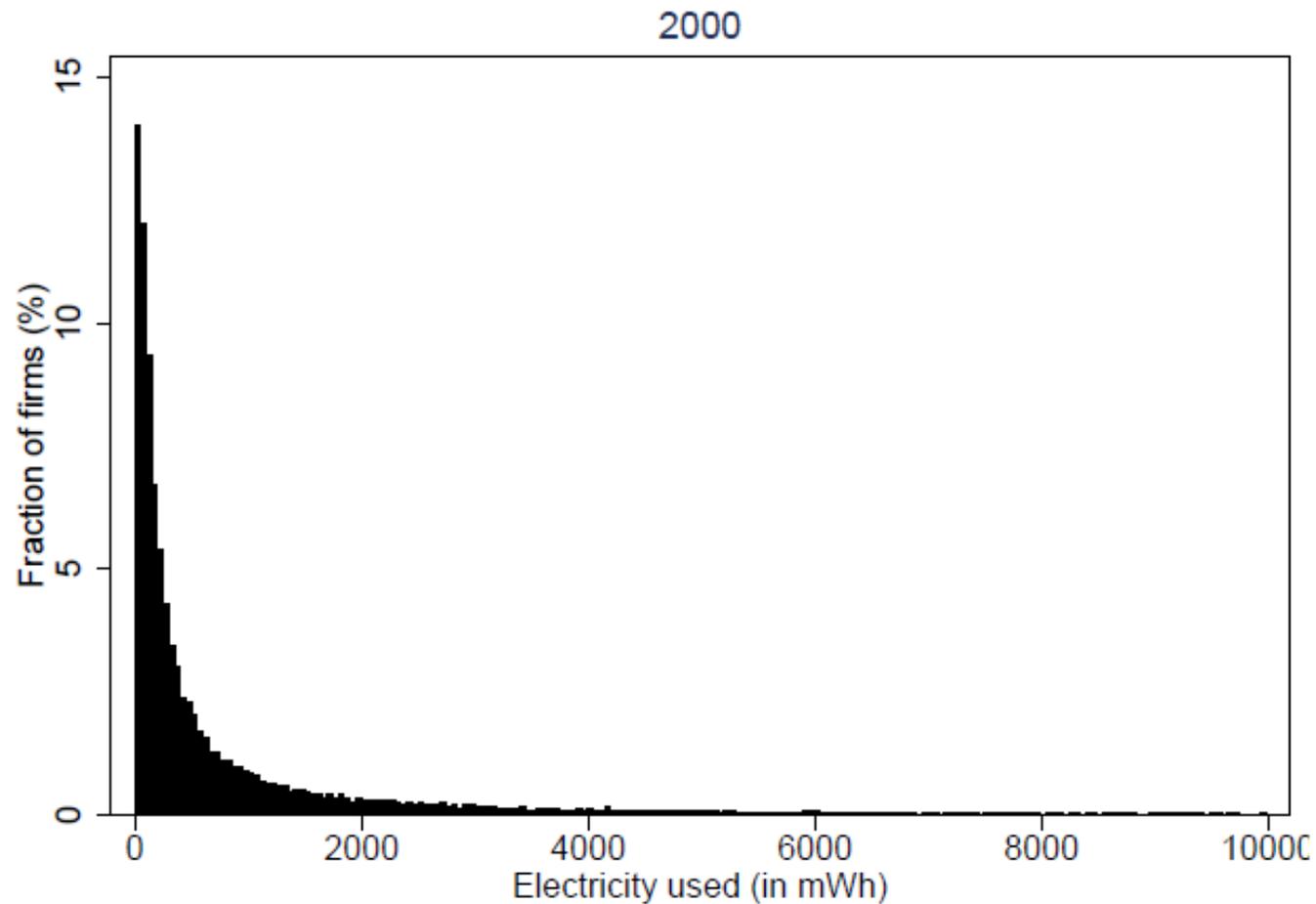
Distribution of the Assignment Variable
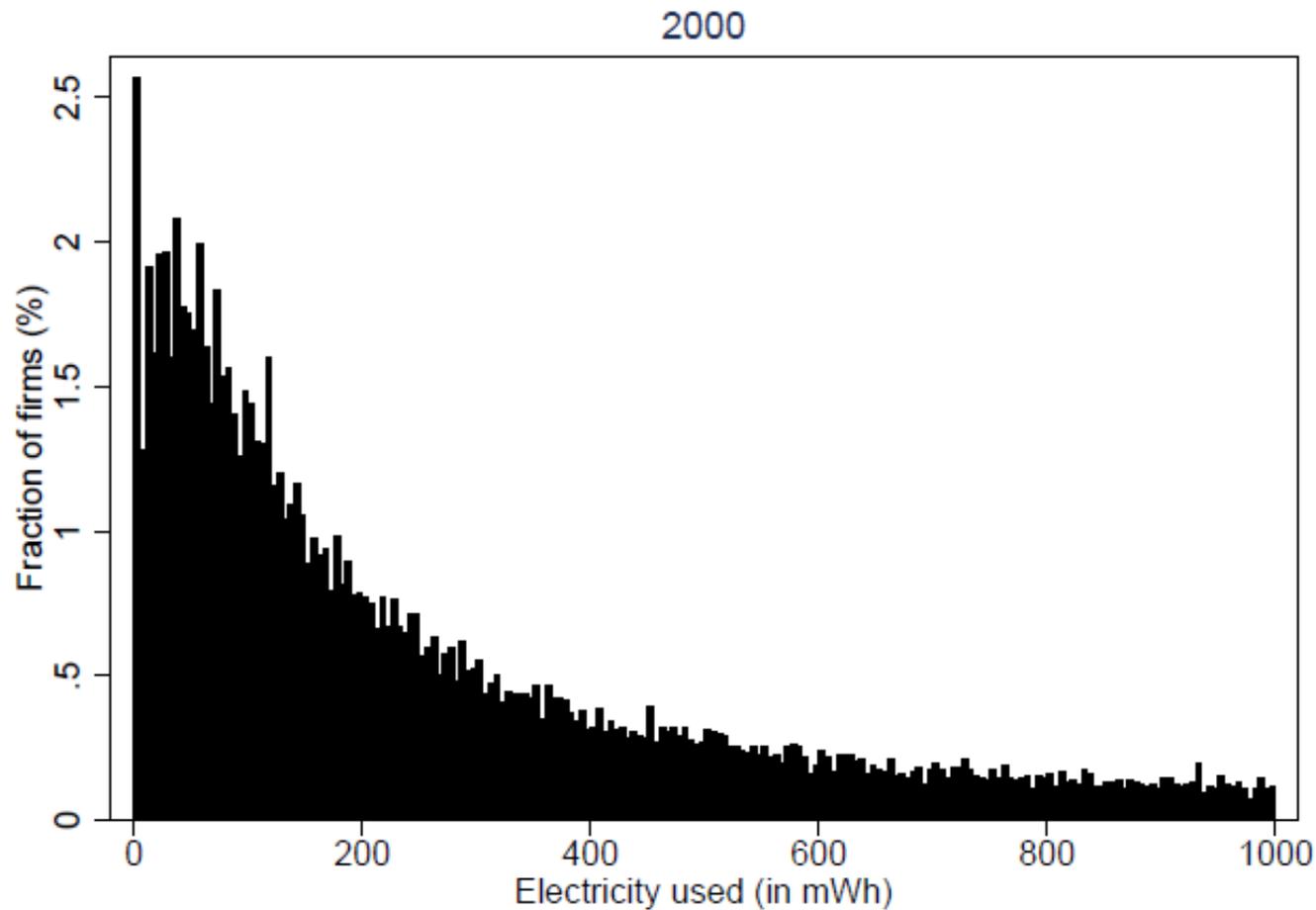
Potential Outcome

Negative effect of reduced marginal electricity tax rate on turnover

Assumptions: i. outcome variables are continous function of electricity use;
ii. firms do not precisely controll the forcing variable electricity use

Results: Local Treatment Effects (ctd)

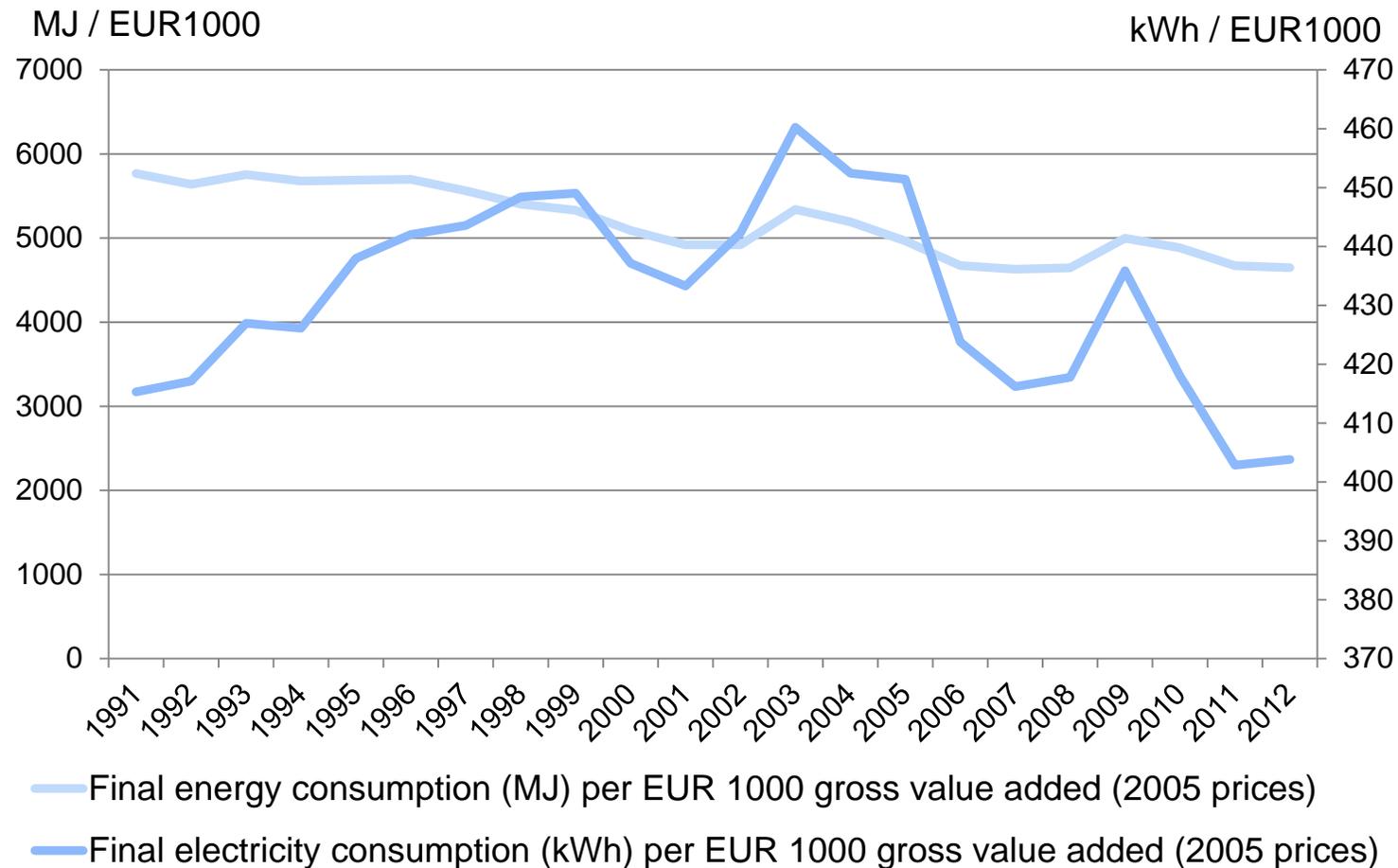| Outcome variable	Estimate	P-Value	Bandwidth	Number of observations	
				Left of c	Right of c
Panel A: 1999					
Turnover	225.290	0.414	7.910	855	872
Number of Employees	-0.065	0.859	7.577	821	828
Investments	-28.089	0.233	6.288	501	485
Turnover Abroad	-83.794	0.618	7.007	331	341
Electricity Intensity	-0.002	0.350	7.999	865	878
Panel B: 2000					
Turnover	-264.170	0.345	8.150	923	868
Number of Employees	-1.771	0.333	8.463	951	888
Investments	16.568	0.428	6.097	523	463
Turnover Abroad	-264.750	0.137	6.477	295	284
Electricity Intensity	0.002	0.444	7.288	837	738
Panel C: 2001					
Turnover	817.670	0.025	5.631	581	680
Number of Employees	1.310	0.498	7.764	790	906
Investments	-9.090	0.478	7.006	514	542
Turnover Abroad	-278.450	0.106	7.109	291	344
Electricity Intensity	-0.004	0.126	6.450	663	759

Turnover, investments and turnover abroader are denoted in EUR 1000.

Relevance: Ambitious Policy Targets

- Objectives European and German climate and energy policy

- EU's 20-20-20 targets set three key objectives for 2020:
    - 20% reduction in greenhouse gas emissions from 1990 levels
    - Raising the share of EU energy consumption produced from renewables to 20%
    - 20% improvement in the EU's energy efficiency (20% saving of the EU's primary energy consumption)

- Germany's targets for 2020:
    - 40% reduction in greenhouse gas emissions from 1990 levels
    - Raising the share of EU energy consumption produced from renewables to 35%
    - doubling of the energy productivity (ratio of gross domestic product to primary energy consumption), based on 1990 figures

Motivation: Incentive Effects

- Specific energy and electricity consumption German industry

Final energy consumption (MJ) per EUR 1000 gross value added (2005 prices)

Final electricity consumption (kWh) per EUR 1000 gross value added (2005 prices)
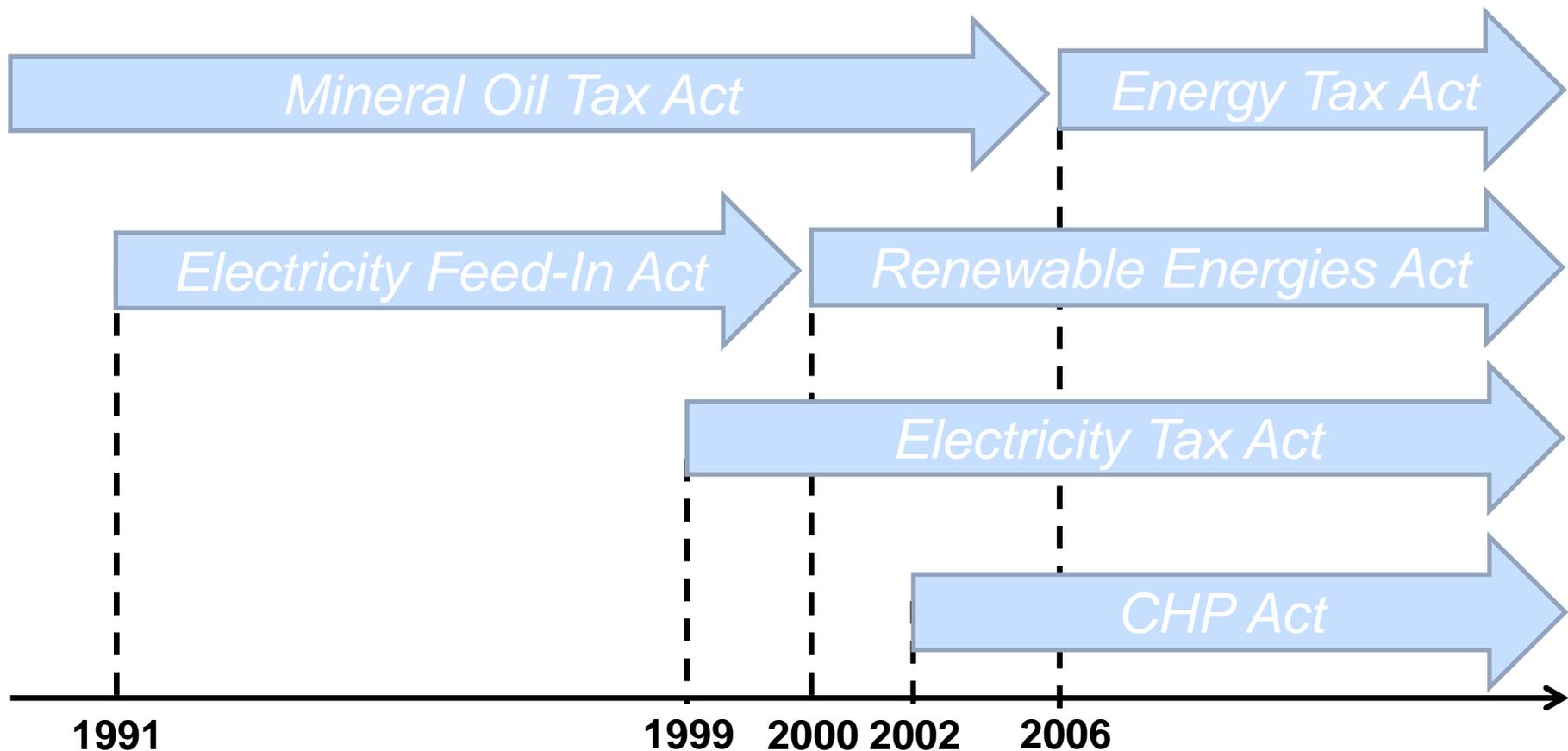
Source: FME

33

Motivation: Effects on Competitiveness

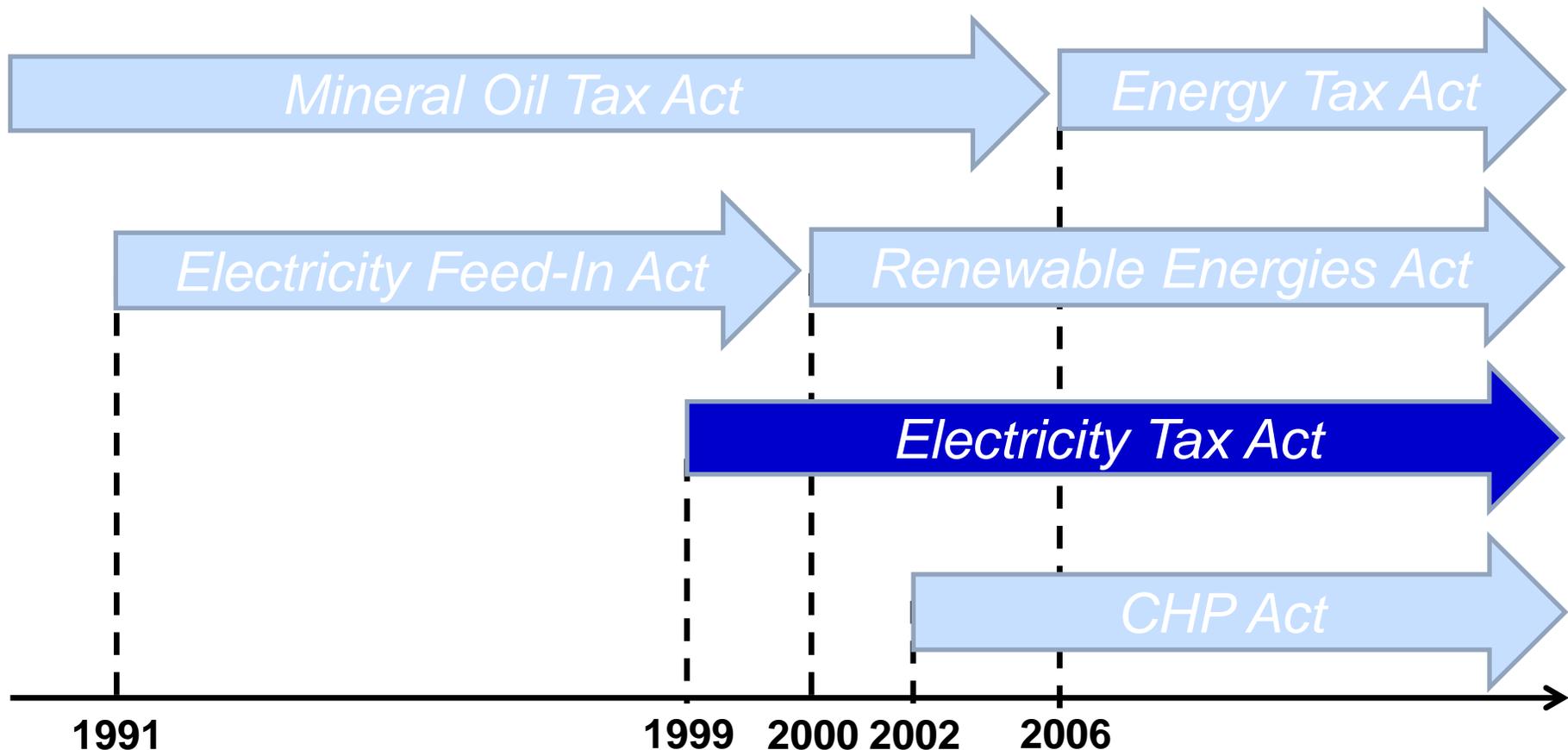- Electricity price for industrial consumers - international comparison
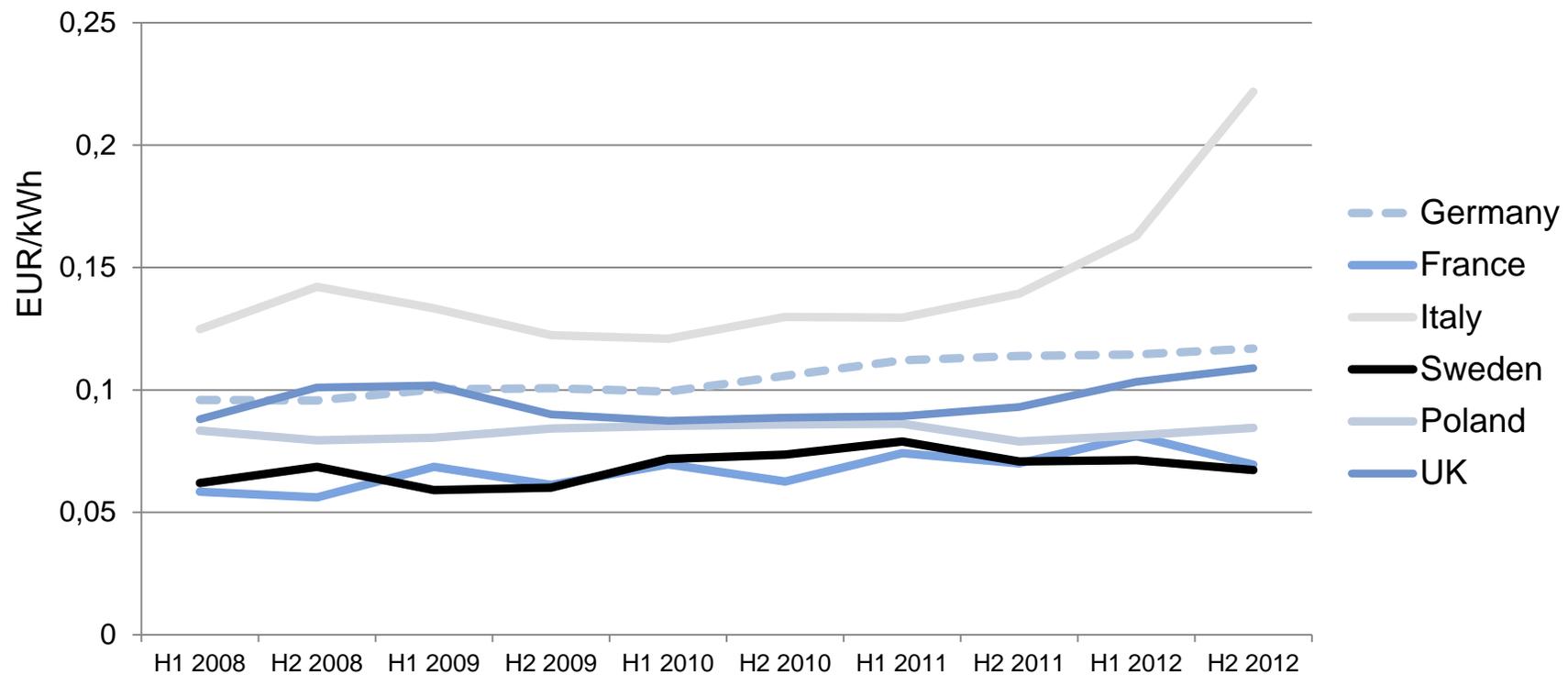
Background and Approach

- Legal development in German energy taxation

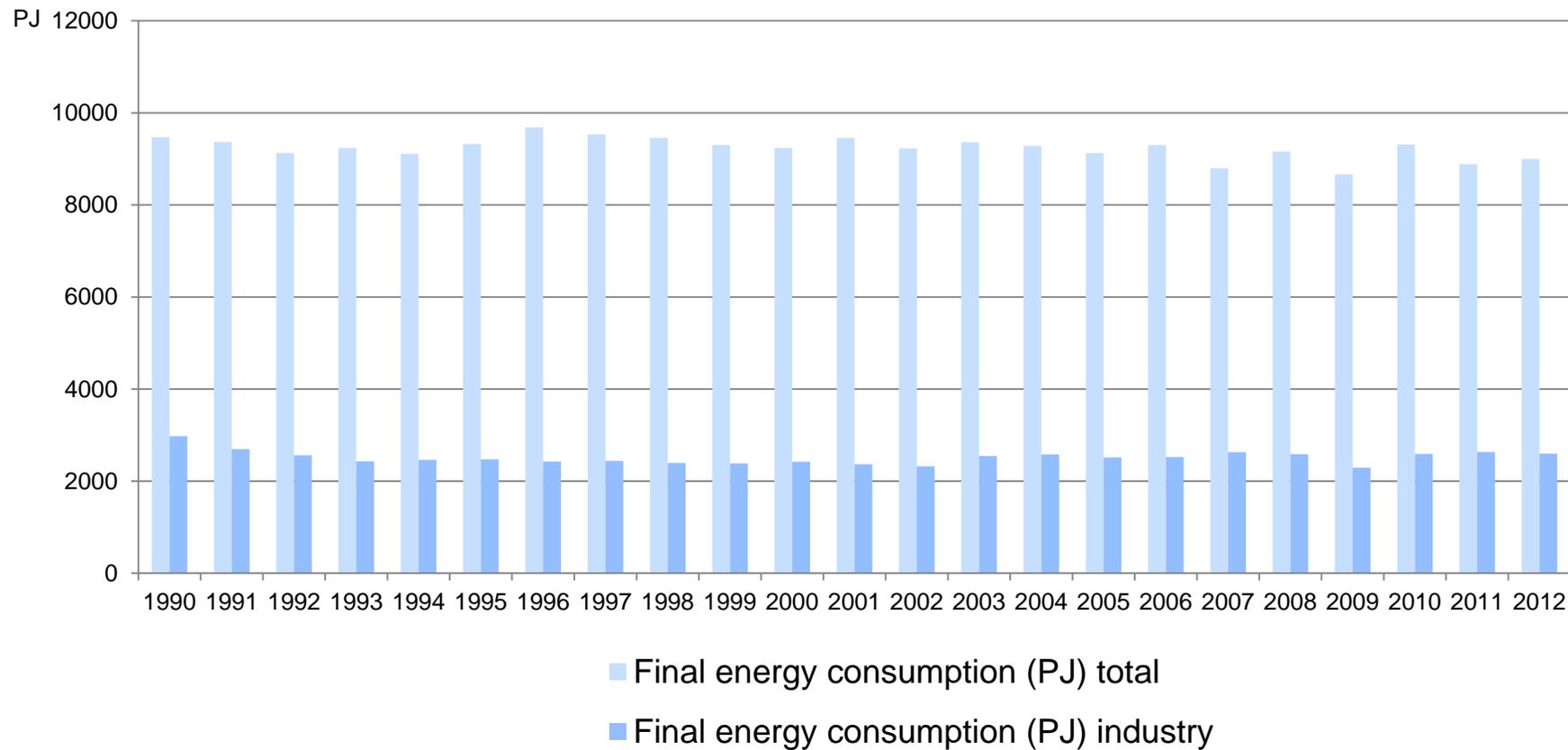# Background and Approach
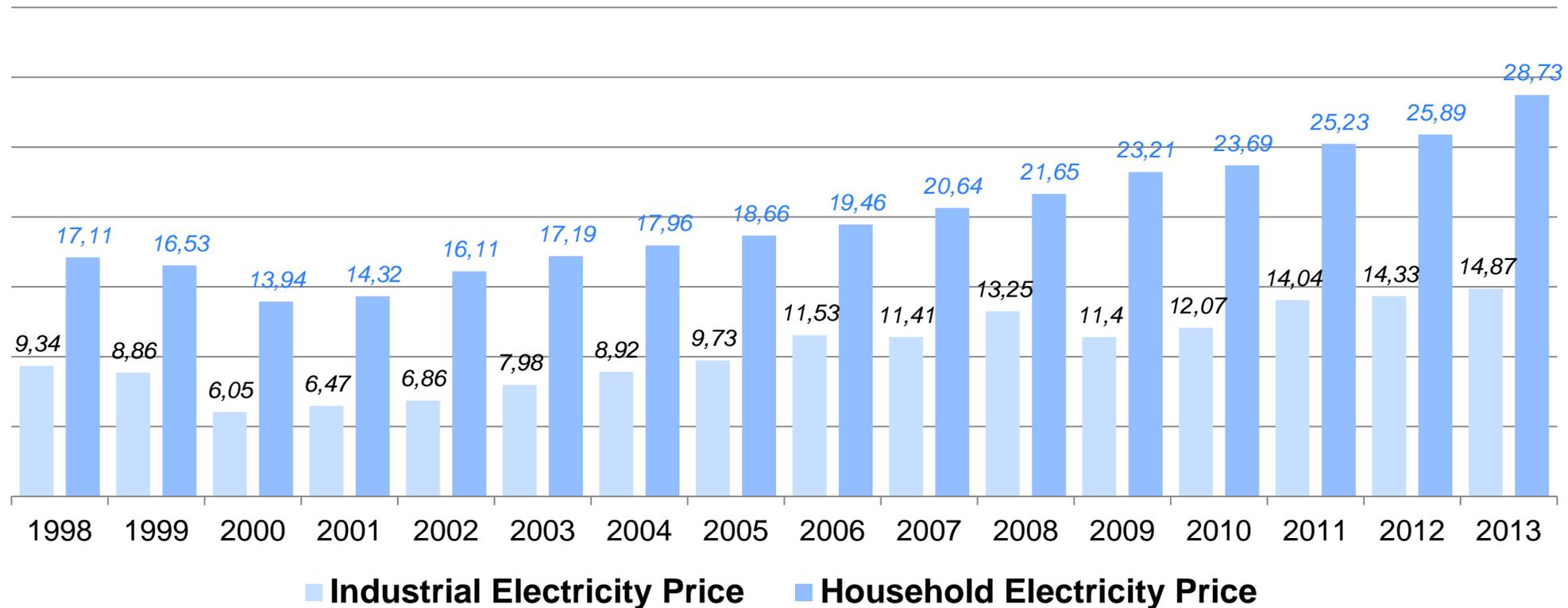
- Legal development in German energy taxation

Mineral Oil Tax Act

Energy Tax Act

Electricity Feed-In Act

Renewable Energies Act

Electricity Tax Act

CHP Act

1991   1999   2000 2002   2006

Relevance

- Final energy consumption Germany

Final energy consumption (PJ) total

Final energy consumption (PJ) industry

Source: FME

Electricity: Price-Development

Comparison of Electricity Prices (Cent/kWh)

Industrial Electricity Price — Household Electricity Price

Year	Industrial Electricity Price	Household Electricity Price
1998	9,34	17,11
1999	8,86	16,53
2000	6,05	13,94
2001	6,47	14,32
2002	6,86	16,11
2003	7,98	17,19
2004	8,92	17,96
2005	9,73	18,66
2006	11,53	19,46
2007	11,41	20,64
2008	13,25	21,65
2009	11,4	23,21
2010	12,07	23,69
2011	14,04	25,23
2012	14,33	25,89
2013	14,87	28,73

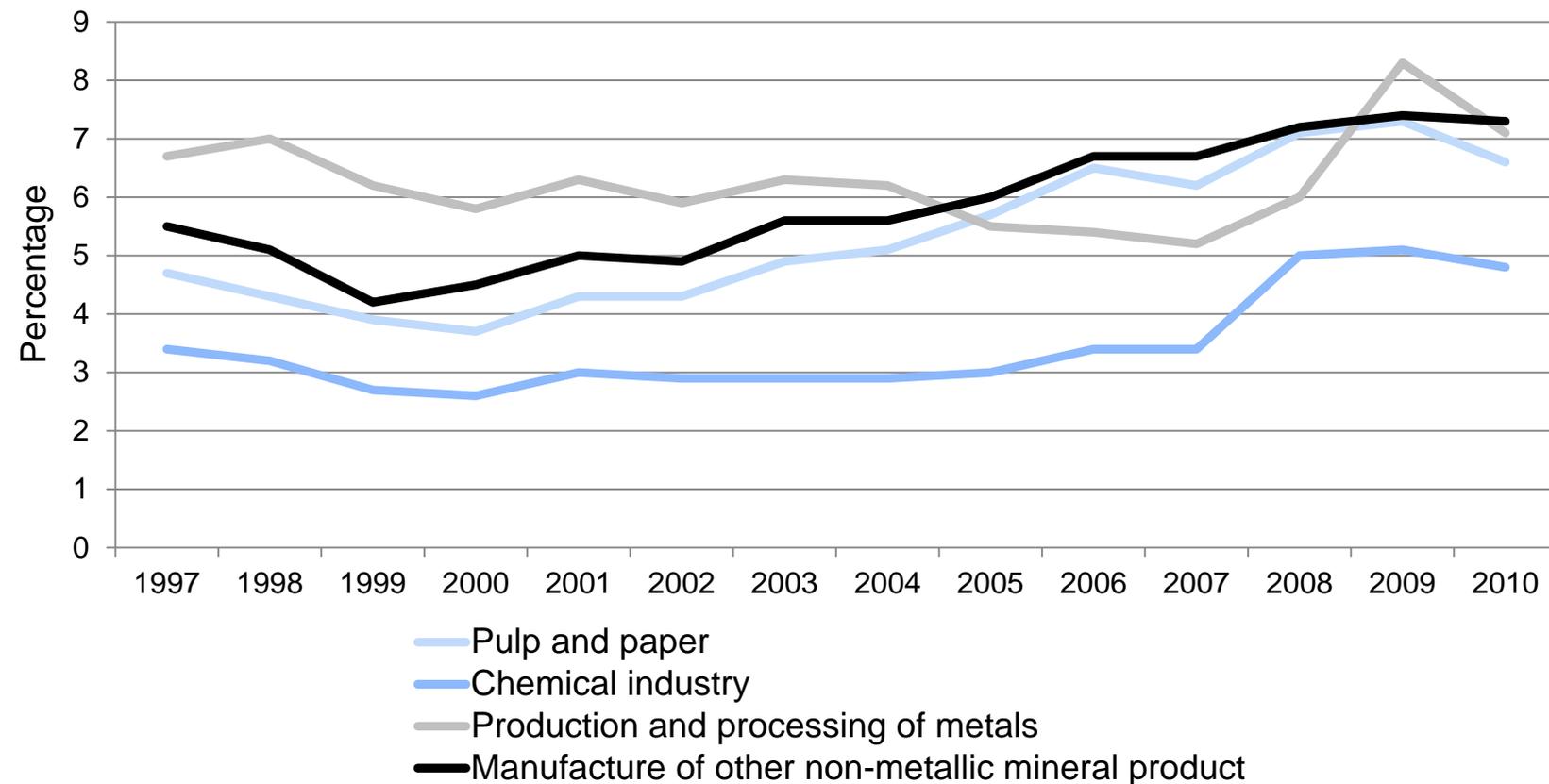**Source: BDEW *Strompreisanalyse May 2013***

Motivation: Effects on Competitiveness

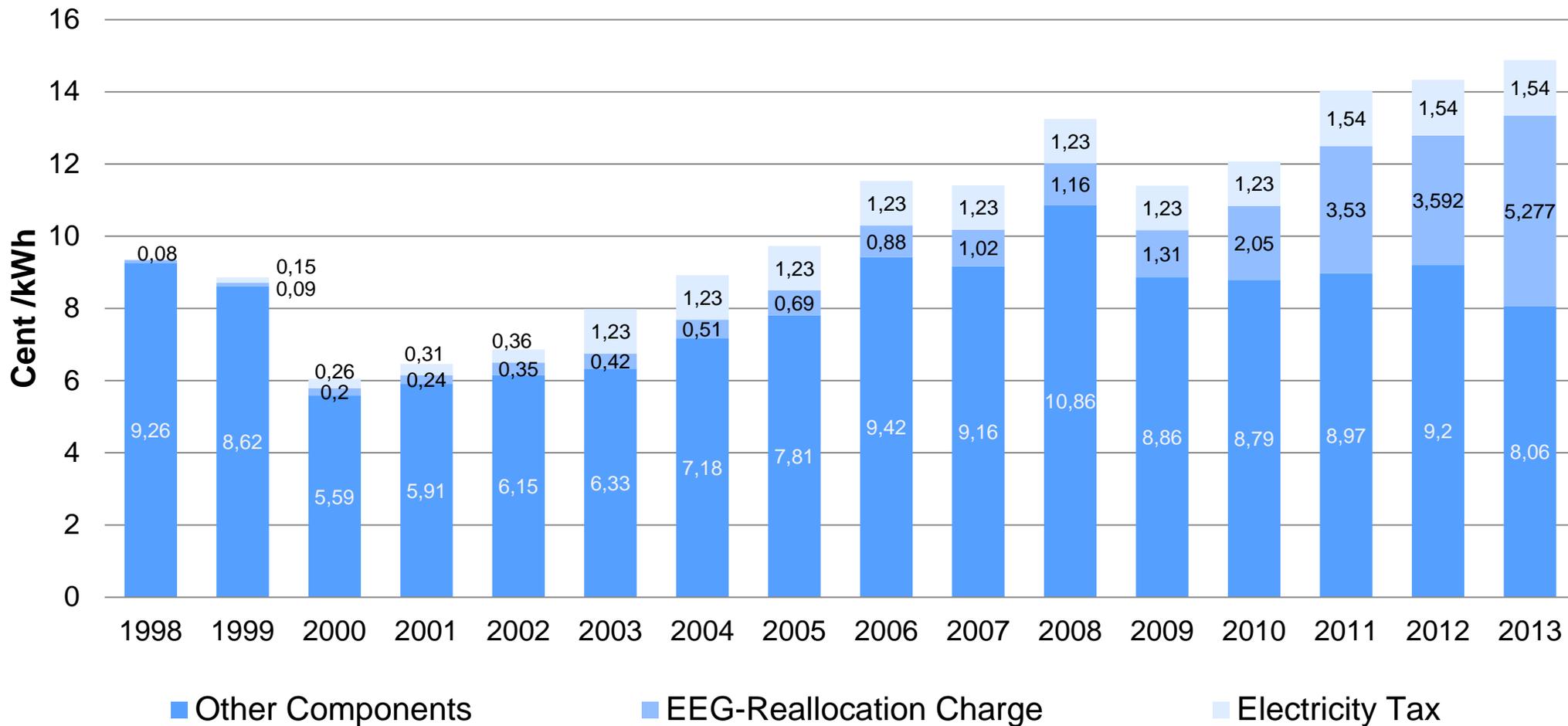- Absolute and relative energy costs of the German industry

Source: FME
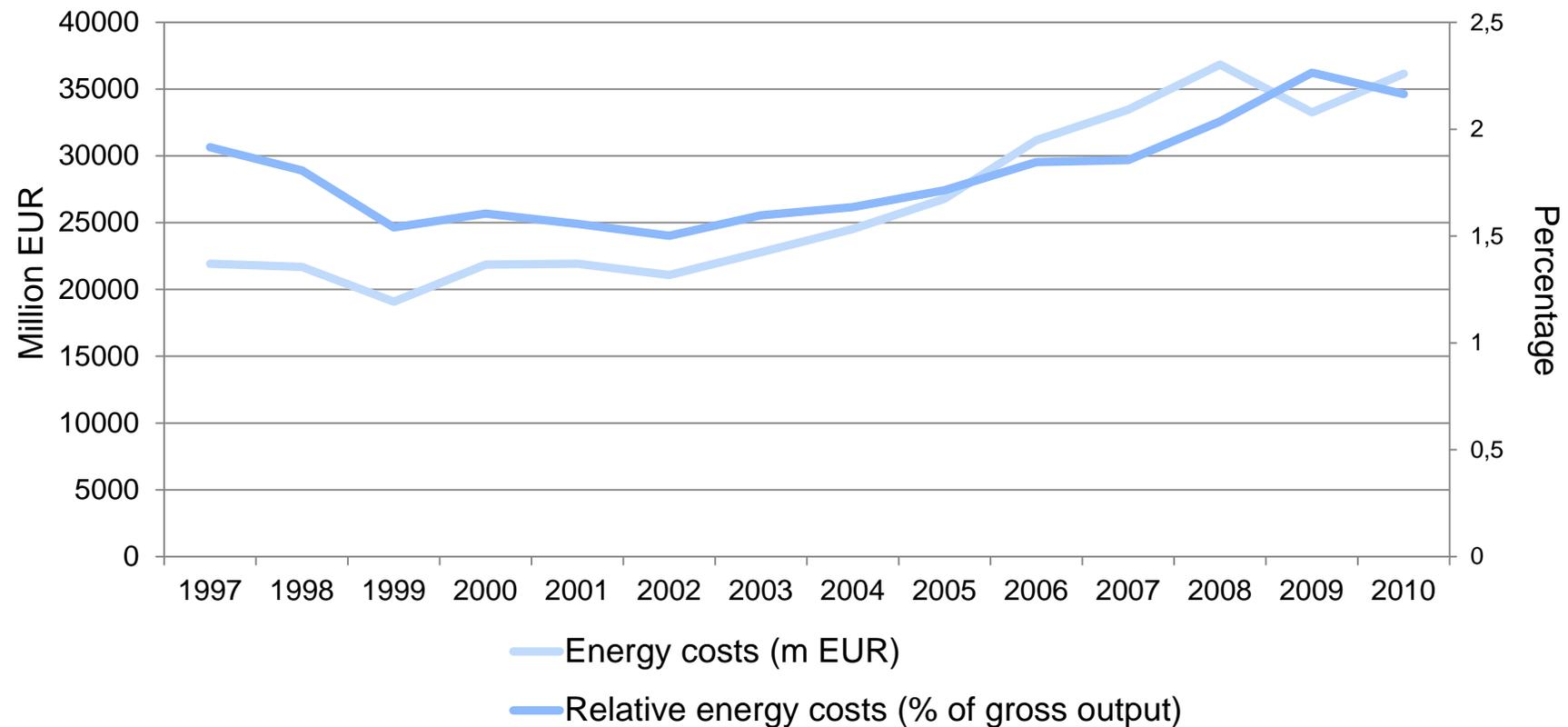
Motivation: Effects on Competitiveness

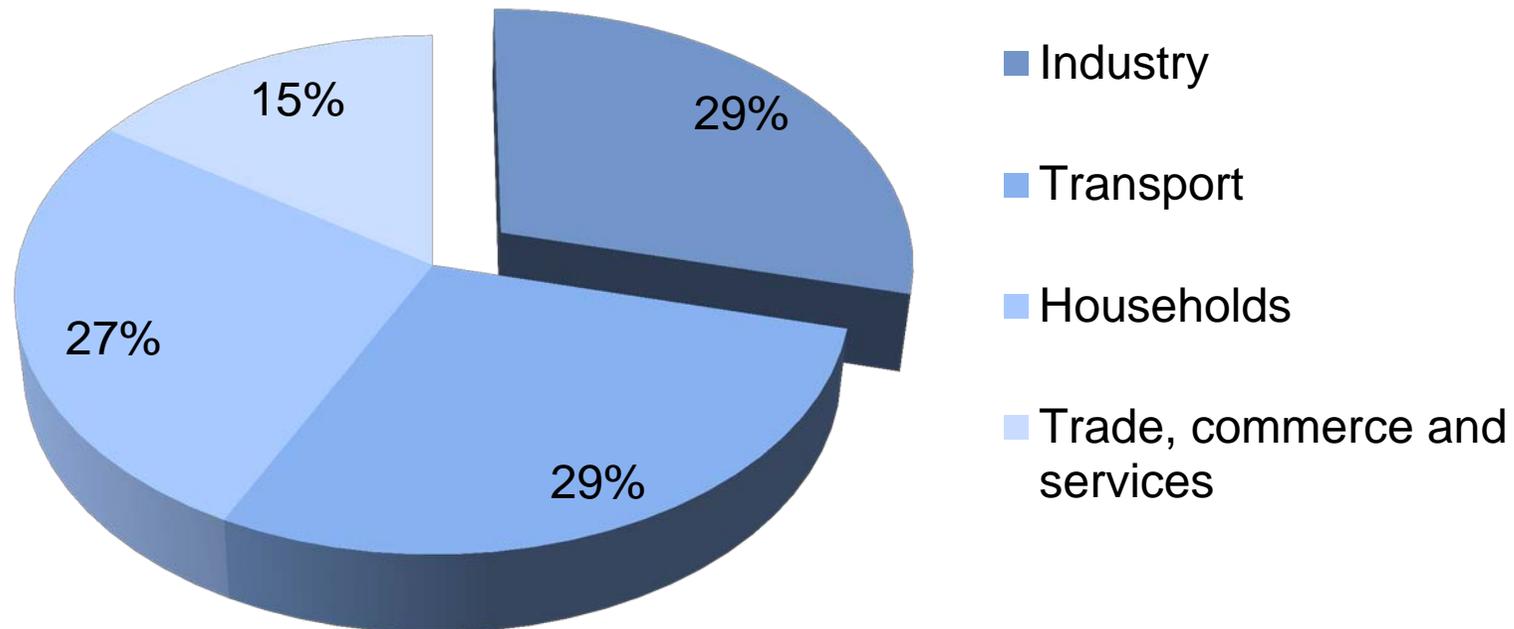- Relative energy costs (% of gross value) energy intensive industries

Source: FME

Relevance

- Final energy consumption Germany

- Industry 29%
- Transport 29%
- Households 27%
- Trade, commerce and services 15%

Source: FME

ZEW

Zentrum für Europäische
Wirtschaftsforschung GmbH

Centre for European
Economic Research