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ORIGINAL ARTICLE

The political economy of energy tax differentiation across industries: theory and empirical evidence

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Abstract We investigate political economy determinants of energy tax differentiation across industries. Based on a theoretical common agency model, we show that differences in the ease of energy demand reductions across industries explain the pattern of tax differentiation: if the government is sufficiently amenable to lobbying efforts, industries with relatively inelastic energy demands will face lower tax rates. An empirical assessment of Germany's environmental tax reform corroborates the findings of our theoretical analysis.

Keywords Energy taxation · Interest groups · Common agency · Regression analysis

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1 Introduction

Over the last decades, energy taxes have played a growing role in environmental policies of OECD countries. As a common feature, energy tax rates are differenti-

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ated across industries. Taxation typically discriminates in favor of energy-intensive industries including complete tax exemptions as an extreme case (OECD 2007).

The differentiation of tax rates for an energy carrier whose combustion triggers uniformly dispersed pollutants such as CO_2 contradicts basic principles of cost-effective environmental regulation. In this paper, we show how political economy considerations may explain the differentiation of energy tax rates across industries. Previous analysis of tax differentiation across industries has focused on the efficiency implications of international spillover effects. Hoel (1996) shows that differentiated taxes may be desirable to counteract emission leakage in the case of unilateral regulation. Tax differentiation across industries might also be motivated by market power of large open economies which strategically exploit terms of trade at the expense of trading partners (Krutilla 1991; Anderson 1992; Rauscher 1994). Quantitative evidence to back these theoretical arguments, however, is rather scant. Drawing on simulations with a computable general equilibrium model based on empirical data, Böhringer et al. (2014) conclude that "in many cases the simple first-best rule of uniform emission pricing remains a practical guideline". In this vein, Böhringer and Rutherford (1997), Babiker et al. (2000), or Kallbekken (2005) identify substantial efficiency costs from differentiating the tax rate on a fossil energy carrier across sectors.

This paper adopts a political economy perspective on energy tax differentiation. We investigate the role of interest groups for energy tax differentiation both in a theoretical as well as an empirical setting.

For our theoretical analysis, we adopt the common agency approach by Grossman and Helpman (1994) to explain energy tax differentiation by lobbying efforts when aggregate energy consumption (as a proxy for environmental targets) is fixed.[1] We demonstrate that, ceteris paribus, a sector with larger lobbying efforts faces lower energy tax rates than sectors with smaller lobbying efforts. More specifically, we find that differences in the ease of energy demand reductions across industrial sectors explain the pattern of tax differentiation: If the government is sufficiently amenable to lobbying efforts, then industries with relatively inelastic energy demands (i.e., a higher incidence from uniform energy taxation) will face lower tax rates.

For the empirical testing of our theoretical predictions, we employ a cross-sectional regression analysis of the German environmental tax reform which was implemented between 1999 and 2003. A central feature of Germany's environmental tax reform is energy tax differentiation in favor of energy-intensive firms. The regression results support the findings of our theoretical analysis on the critical role of energy demand elasticities.

Our study is related to previous research on political economy determinants of environmental taxation: Frederiksson (1997) and Aidt (1997, 1998) investigate the implications of international competition and revenue recycling for the design of

[1] Oates and Portney (2003) discuss alternative positive theories on the role of interest groups in environmental policy formation: (i) rent-seeking models describe how interest groups compete for group-specific rents (Tullock 1980), specifically in the context of environmental instrument choice (Dijkstra 1998); (ii) probabilistic-voting models assume that lobby groups influence policy makers through the potential, yet uncertain votes of their members (Coughlin 1992); (iii) models of information transfer refer to the exchange of truthful information between interest groups and policy makers, upon which politicians base their decisions (Grossman and Helpman 2001; Naevdal and Brazee 2000; Potters and Winden 1992).

environmental tax reforms. Cremer et al. (2004) adopt a voting model to analyze how political support for environmental taxes depends on the revenue rebating scheme. Polk and Schmutzler (2005) present a theoretical model where two interest groups can lobby for a general tax rate or sector-specific favors.

To our best knowledge, our analysis constitutes the first quantitative assessment of the role of interest groups in energy (environmental) tax differentiation. Previous empirical studies have analyzed the role of lobbying with respect to other environmental policy instruments such as "command and control" regulation or the allocation of emission permits. Fredriksson et al. (2004) assess the effect of corruption and industry size on energy efficiency regulations. They find that higher costs for lobby group coordination (i.e., larger sector size) increase energy policy stringency, while greater corruptibility of policy makers reduces it. Joskow and Schmalensee (1998) investigate how the American Congress, influenced by various special interests, distributed SO_2 allowances among electric utilities under the U.S. acid rain program. A complementary study by Burkey and Durden (1998) on this program confirms that financial contributions significantly influenced the voting patterns of politicians. In a similar vein, Hanoteau (2003) measures the level of rent-seeking efforts by contributions from Political Action Committees and shows that industrial lobbying can influence the allocation of emission allowances.

The remainder of this paper is organized as follows. In Sect. 2, we describe our common agency framework and derive differentiated energy taxes under political economy considerations. In Sect. 3, we present our empirical analysis on determinants of energy tax differentiation for the case of Germany. In Sect. 4, we conclude.

2 A political-economy model of differentiated energy taxes

We develop a common agency model of a small open economy in order to investigate political economy motivations for energy tax differentiation between sectors. Our model is in the tradition of Aidt (1998) and Grossman and Helpman (1994): Lobbying of sectors affects the policy choice of the government (the regulator) which is not only interested in social welfare but also values political support by interest groups.

We consider an economy with $s = 1, \ldots, n$ production sectors. Within a sector s, competitive firms produce output by using labor l_s and energy e_s. Energy is imported from the world market at unit costs $\bar{z}$. Output q_s of sector s is produced by means of a concave production function $f^s(e_s, l_s)$. To simplify the exposition of our results, we assume that the production decisions on labor and energy are separable, i.e., $\partial^2 f^s / \partial e \partial l(e_s, l_s) = 0$. Output can be sold at the exogenous world market price $\bar{p}_s$. The assumption of competitive world markets implies that we do not have to consider consumption choices and consumer surplus in the domestic market. More generally, a sector could face a downward sloping demand if no (perfect) substitutes are produced by producers abroad. Then, domestic policy could exploit terms of trade (see Böhringer et al. 2014). We abstract from such terms-of-trade effects in our theoretical analysis in order to focus on the impact of lobbying efforts on tax differentiation.

Reflecting wide-spread policy practice (OECD 2001, 2007) the environmental tax reform is assumed to redistribute energy taxes via reductions in labor costs. The regulator taxes energy at a rate τ_s such that firms face unit costs of energy $z_s = \bar{z} + \tau_s$. As to the treatment of labor cost, we follow Bovenberg and Ploeg (1996) in assuming that labor supply is rationed by a (uniform) exogenous employees' wage $\bar{w}_e$, i.e., the net wage. The gross wage to be paid by the employers differs from the net wage because of labor taxes and social security contributions. We denote the gross wage prior to the tax reform by $\bar{w}_p$. The revenues from environmental taxes are earmarked to reduce the tax wedge between $\bar{w}_e$ and $\bar{w}_p$. The effective producer wage is therefore given by $w = \bar{w}_p - \sigma$ where the reduction σ of the gross wage will be endogenously determined by the energy tax yield.

We assume that the regulator taxes energy in order to comply with an aggregate energy consumption ceiling $\bar{E}$ for environmental reasons (with polluting emissions being proportionally linked to energy use):

$$\bar{E} = \sum_s e_s \tag{1}$$

The energy tax yield is earmarked for reducing labor costs:

$$\sigma \sum_s l_s = \sum_s \tau_s e_s \tag{2}$$

Profits at the sectoral level are given by:

$$\pi_s = \bar{p}_s f^s(e_s, l_s) - (\bar{z} + \tau_s)e_s - (\bar{w}_p - \sigma)l_s \tag{3}$$

and social welfare by:

$$W = \bar{w}_e \sum_s l_s + \sum_s \pi_s + \psi \left[\sum\nolimits_s \tau_s e_s + (\bar{w}_p - \bar{w}_e - \sigma)l_s \right] \tag{4}$$

where $\psi \geq 1$ denotes the marginal social benefit of public revenue. Social welfare thus consists of net wage earnings, sector profits, and public revenues valued at the marginal social benefit. Since aggregate energy consumption associated with polluting emissions is fixed exogenously, we can neglect the explicit treatment of damages in our analysis.

Production decisions by competitive profit maximizing firms are characterized by the usual first-order conditions:

$$\bar{p}_s f_e^s(e_s, l_s) = \bar{z} + \tau_s \quad \bar{p}_s f_l^s(e_s, l_s) = \bar{w}_p - \sigma \tag{5}$$

and application of the envelope theorem yields:

$$\frac{d\pi_s}{d\tau_s} = -e_s \quad \frac{d\pi_s}{d\sigma} = l_s \tag{6}$$

2.1 Political interests

The government chooses a tax scheme $TS = ((\tau_1, \ldots, \tau_n), \sigma)$ that achieves $\bar{E}$ (condition (1)] and uses the energy tax yield to reduce labor costs [condition (2)]. In the design of the tax scheme, the government does not only consider social welfare but also contributions (political support) $C_s(TS)$ by lobby groups. We assume that there is a lobby group for each sector s representing (a fraction of) the firms or likewise profits in the respective sector. The weight by which contributions are valued on behalf of the government is denoted by λ. Thus, the government maximizes:

$$W(TS) + \lambda \sum_s C_s(TS) \tag{7}$$

Within each sector, lobbying represents a public good and a single firm has incentives to free-ride on the lobbying efforts of other firms in the same sector. We assume that the degree to which a sector can overcome these free-riding problems is measured by the fraction $\kappa_s \in [0, 1]$ of total profits π_s represented by the respective lobby group.[2]

Before the government decides upon the tax system TS, each lobby group offers a menu of contributions (political support), $C_s(TS)$ as a function of the government's policy choice, in order to maximize profits in its sector (Bernheim and Whinston 1986). In our analysis, we focus on the equilibrium which is given by each lobby group truthfully reporting their costs and benefits from the respective policy (see, e.g., Grossman and Helpman 1994 or Aidt 1998 for a proof of existence). Each contribution schedule $C_s(TS)$ is hence given by $\kappa_s \pi_s$ (less some constant).

The decision problem (7) of the government then corresponds to the maximization of:

$$G(TS) = W(TS) + \lambda \sum_s \kappa_s \pi_s(TS) \tag{8}$$

by choosing $(\tau_s)_s$ and σ subject to (1) and (2).

Denoting the Lagrange multipliers for (1) and (2) by μ_1 and μ_2, and aggregate labor demand by $L = \sum_s l_s$, we can derive the following expression for the tax rates in the respective sectors (see Appendix):

$$\tau_s = -\bar{z} + \frac{\mu_1 + (\psi - \mu_2)\bar{z}}{(\psi - \mu_2) - (\psi - \mu_2 - \lambda\kappa_s - 1)/\eta_s} \tag{9}$$

where $\eta_s = (-\frac{\partial e_s}{\partial \tau_s}/e_s)(\bar{z}+\tau_s)$ denotes the price elasticity of energy demand in sector s.

[2] $(\kappa_s)_s$ thereby depends on the organizational structure of the sector such as market concentration which will be used as one explanatory variable in the empirical part of the paper (see Sect. 3). The sector's incentives to get organized, i.e., to increase κ_s, clearly also depend on the sector's influence on the government's policy choice (i.e., the impact of κ_s on sectoral profits). In the following, we focus on the policy choice as a function of $(\kappa_s)_s$.

2.2 The determinants of tax differentiation

We use condition (9) to discuss the determinants of tax differentiation in our political economy framework. Condition (9) implies that:[3]

$$\tau_s < \tau_{s'} \Leftrightarrow (\psi - \mu_2 - \lambda\kappa_s - 1)/\eta_s < (\psi - \mu_2 - \lambda\kappa_{s'} - 1)/\eta_{s'} \tag{10}$$

Ceteris paribus, for two sectors which only differ in their lobbying efforts (measured by κ_s), the one with stronger lobbying efforts (κ_s) faces a smaller tax rate. The equilibrium tax rates also depend on the sector-specific price elasticities (η_s) of energy demand. Sectors with less elastic energy demand face a higher tax if $\psi - \mu_2 - \lambda\kappa_s - 1 > 0$; in turn, if $\psi - \mu_2 - \lambda\kappa_s - 1 < 0$, sectors with less elastic energy demand face a lower tax. This suggests that—in equilibrium—there is an interaction between effective lobbying power (indicated by the product $\lambda\kappa_s$ of the government's weight λ to contributions times sector-specific lobby efforts κ_s) and the elasticity of energy demand regarding their impact on the tax rate: While sectors with weak effective lobbying power would receive a higher (lower) tax rate if they have relatively inelastic (elastic) energy demand, for sectors with strong effective lobbying power this result is reversed.

It should be noted that these relationships hold also without considering the environmental goal (i.e., $\mu_1 = 0$) or the restriction on using the energy tax yield to reduce labor costs ($\mu_2 = 0$). In this case, the sector-specific energy tax $\hat{\tau}_s$ is:

$$\tau_s = \hat{\tau}_s = -\bar{z} + \bar{z}\frac{\psi}{\psi - (\psi - \lambda\kappa_s - 1)/\eta_s} \tag{11}$$

such that taxes are differentiated due to the cost of public funds ($\psi > 1$) and/or lobbying. When introducing the environmental goal of constrained energy use ($\mu_1 > 0$), a further tax differentiation results:

$$\tau_s - \hat{\tau}_s = \frac{\mu_1}{\psi - (\psi - \lambda\kappa_s - 1)/\eta_s}. \tag{12}$$

That is, even when starting from a tax system which already differentiates taxes due to tax yield effects *and* lobbying efforts, the *additional* energy tax rates are differentiated. Earmarking of the tax revenues ($\mu_2 \neq 0$) does not qualitatively change this result. Energy tax differentiation therefore follows the same determinants [see condition (10)] if starting from a zero or an efficient tax system. For simplicity, we therefore refer in our discussion to the determinants of the tax as given in (9) and (10).

We show the following proposition in Appendix:

Proposition *(i) If two sectors have identical energy demand elasticity (η_s), the sector with stronger lobbying efforts (κ_s) faces a lower tax rate (τ_s). (ii) If two sectors have identical lobbying efforts, the sector with less elastic energy demand is taxed more (less) if the impact of lobbying on regulatory decisions is sufficiently weak (strong), i.e., if the valuation λ of political support by lobby groups is sufficiently small (large).*

[3] Condition (16) in the Appendix implies that $\psi - \mu_2 - 1 > 0$.

The proposition implies that the impact of the energy demand elasticity on taxes crucially depends on how the government weighs lobby support. In other words, there is a strong interaction between energy demand elasticities and the effectiveness of lobbying on tax rates. If regulatory decisions are barely affected by lobbying (i.e., the effective lobby power in terms of $\lambda\kappa_s$ is very small), sectors with less elastic energy demand face a larger tax rate, confirming the traditional Ramsey formula prediction that taxing sectors with less elastic energy demand is beneficial in terms of generating tax yield. If, however, the regulator can easily be influenced by lobbying, this relationship is reversed such that sectors with less elastic energy demands then face lower tax rates. Intuitively, taxation would induce high tax payments and therefore heavily reduce profits in sectors with inelastic energy demand. As lobbying is targeted towards the increase of profits, stronger lobbying will lead to a smaller tax.

3 Regression analysis of the German environmental tax reform

In order to test our theoretical findings, we perform a regression analysis based on data for environmental taxes in Germany. Between 1999 and 2003, Germany implemented an environmental tax reform. The reform levied higher taxes on energy use while recycling the additional energy tax revenue through a reduction of employer's social security contributions (see Kohlhaas 2000). In our regression analysis, we aim at assessing determinants of environmental tax differentiation across sectors.[4]

3.1 Variables

We test our theoretical predictions on the extent and the determinants of tax differentiation employing three energy tax components of the German reform as dependent variables: the average *effective* taxes on electricity, gas and fuel oil use (i.e. taxes including reductions). In addition, we study to which extent sectors succeeded in lowering their net burden from the tax reform. Taking into account tax payments as well as the redistribution via the reduction in labor costs, we use the net burden as a fourth dependent variable.[5]

The average effective taxes on electricity, gas, and fuel oil as well as the net burden of the reform are explained at the sectoral level by six independent variables. Reflecting our theoretical model of Sect. 2, we employ lobbying efforts and price elasticities of energy demand as explanatory variables. We furthermore include energy intensity, employment level, market concentration, and exposure to international trade as explanatory variables to control for central objectives and implementation features of the environmental tax reform. Intensities for electricity, gas, fuel oil, and overall energy are employed as independent variables because the environmental tax reform in Germany explicitly granted tax breaks to energy-intensive sectors. The incorpora-

[4] Due to the sectoral classification of the German economy, the number of observations in our dataset is limited which calls for the use of robust estimation techniques.

[5] The net burden results from total energy tax payments less reimbursements in terms of reduced social security contributions by employers.

tion of the sectoral employment level as an independent variable allows us both to investigate labor market aspects of the reform and to control for sector size (given that the variable is highly correlated with sectoral output levels). Market concentration accounts for the degree of interest organization while trade exposure reflects popular arguments against (unilateral) environmental taxation with respect to international competitiveness. Finally, we investigate the role of interactions between lobbying efforts and energy demand elasticities in order to analyze our theoretical proposition of Sect. 2.

3.2 Data

The cross-sectional regression analysis covers all 42 manufacturing sectors of the German economy as provided by the official input-output classification (see Table 1).

Our sector-level data set for Germany has been compiled from various sources. Data on sectoral tax rates and net burdens are provided by Bach et al. (2001, 2003) who also report sectoral energy use for electricity, gas, and oil. Sectoral production and employment data are taken from official input-output tables, and sector-specific price elasticities of energy demand are based on Capros et al. (1999).

Since there is no direct indicator of lobbying efforts (κ_s), we adopt the approach of other empirical studies (Delaney et al. 1988; Goldstein and Bearman 1996) and use the number of lobby representatives of the major industrial association in each sector as a proxy measure for lobbying efforts (see Table 1 for a mapping between sectors and respective associations as well as the number of representatives). The measure describes political influence via the representation of sectoral interest vis-à-vis the policymaker: efforts towards political influence are the higher, the more representatives a lobby employs.[6]. Regarding the sectoral structure of associations, we use the classification of the Federation of German Industries which represents the highest level of political representation of the private sector and comprises all major industrial associations in Germany. This classification implies that some associations represent more than one sector and some sectors are represented by more than one association, which is consistent with the actual policy process. Here, it is assumed that each lobby representative has the same importance in the policy process, regardless if she represents one or more sectors. Data on the number of lobby representatives of German industrial associations was collected by means of a comprehensive telephone survey.[7]

6 Differently from lobbying in other countries, say, in the U.S., campaign contributions are not a feasible measure of political influence in Germany. Instead, information transfer and person-to-person interactions traditionally play a more important role. The contributions of a sector are therefore related to its expenses for lobby representative such that we can use their number as a proxy for lobby efforts. An exemplary channel of political influence is information transfer between interest groups and policy makers [see Grossman and Helpman (2001), Naevdal and Brazee (2000) or Potters and Winden (1992)].

7 The survey has been conducted at the Centre for European Economic Research (ZEW) in Mannheim, Germany, during June and July, 2004. Contact details of associations were taken from a database of German industrial organizations (Hoppenstedt 2003). For each of the 42 manufacturing sectors of the German economy we covered the representative industrial associations, the majority of which are at the same time members of the Federation of German Industries (BDI).

Table 1 German manufacturing sectors (Input-output classification) and respective industrial associations with number of representatives

Sector no.	Name of sector (IOT 1993)	Industrial associations	Number of representatives
1	Agricultural products	German Farmers Association (DBV)	85
2	Forestry & fishery products	German Forestry Council (DFWR)	11
		German Fishery Association (DFV)	
3	Electric power & steam & warm water	German Electricity Association (VDEW)	160
4	Gas	Association of the German Gas and Water Industries (BGW)	128
5	Water (distribution)	Association of the German Gas and Water Industries (BGW)	128
6	Coal & coal products	German Mining Association (WVB)	99
		German Hard Coal Association (GVST)	
		German Lignite Industry Association (DEBRIV)	
7	Minery products (w/o coal, gas, petroleum)	German Mining Association (WVB)	10
8	Crude oil & natural gas	Association of the German Oil and Gas Producers (WEG)	7
9	Chemical products & nuclear fuels	Association of the German Chemical Industry (VCI)	195
10	Oil products	Association of the German Petroleum Industry (MWV)	25
11	Plastics	Association of the German Plastics Processing Industry (GKV)	34
		Federation of German Woodworking and Furniture Industries (HDH)	
		Fed. of German Paper, Cardboard and Plastics Processing Ind. (HPV)	
12	Rubber	German Rubber Manufacturers' Association (WDK)	30
13	Stone & lime & cement	German Building Materials Association (BBS)	8
14	Ceramic	German Federation of Fine Ceramic Industry (AKI)	6

Table 1 continued

Sector no.	Name of sector (IOT 1993)	Industrial associations	Number of representatives
15	Glass	German Glass Industry Federation (BV Glas)	11
16	Iron & steel	German Steel Federation (WV Stahl)	47
		German Federation of Steel and Metal Processing (WSM)	
17	Non-ferrous metals	Federation of the German Non-Ferrous Metals Industry (WVM)	40
		Federation of German Steel and Metal Processing (WSM)	
18	Casting products	German Foundry Association (DGV)	30
19	Rolling products	Association of German Drawing Mills (STV)	10
		Association of German Cold Rolling Mills (FVK)	
20	Production of steel etc	German Structural Steel and Power Engineering Association (SET)	3
21	Mechanical engineering	Federation of the German Engineering Industry (VDMA)	350
22	Office machines	–	0
23	Motor vehicles	Association of the German Automotive Industry (VDA)	70
24	Shipbuilding	German Shipbuilding and Ocean Industries Association (VSM)	12
25	Aerospace equipment	German Aerospace Industries Association (BDLI)	19
26	Electrical engineering	German Electrical and Electronic Manufacturers' Association (ZVEI)	150
27	Engineers' small tools	German Industrial Association for Optical, Medical and Mechatronical Technologies	28
		Federation of German Jewellery, Watches, Clocks, Silverware and Related Industries	
28	Metal and steel goods	–	0
29	Music instruments & toys etc.	National Association of German Musical Instruments Manufacturers (BDMH)	4
		German Association of the Toy Industry (DVSI)	

Table 1 continued

Sector no.	Name of sector (IOT 1993)	Industrial associations	Number of representatives
30	Timber	Federation of German Woodworking and Furniture Industries (HDH)	14
		Association of the German Sawmill and Wood Industry (VDS)	
31	Furniture	Federation of German Woodworking and Furniture Industries (HDH)	9
32	Paper & pulp & board	German Pulp and Paper Association (VDP)	41
33	Paper & board products	German Pulp and Paper Association (VDP)	51
		Federation of German Paper, Cardboard and Plastics Processing Industry (HPV)	
34	Printing and publishing	German Printing Industry Federation (BVDM)	40
35	Leathers & footwear	German Leather Federation (VDL)	13
		Federation of the German Shoe Industry (HDS)	
36	Textiles	Federation of German Textile and Fashion Industry	28
37	Clothing	Federation of the German Clothing Industry (BBI)	30
38	Food products	Federation of the German Food and Drink Industries (BVE)	9
39	Beverages	Federation of the German Food and Drink Industries (BVE)	9
40	Tobacco products	Federation of the German Cigarette Industry (VdC)	25
41	Building & construction	German Construction Industry Federation (HDB)	55
42	Recovery & repair	German Construction Industry Federation (HDB)	55

As a standard measure for market concentration, we employ the average sectoral Herfindahl–Hirschman Index (HHI).[8] Market concentration data is provided by the German Monopolies Commission (German 2004a, b). Exposure to international trade is captured by sector-specific Armington elasticities of substitution between imports

[8] The HHI is calculated by squaring the market share of each firm competing in the respective market/sector and summing up the resulting numbers.

and competing domestic goods. Estimates for Armington elasticities are taken from Welsch (2007).

For reasons of consistency, we employ the following years of observation: energy use data is taken from 1998 which served as the reference year for the design of the environmental tax reform initiated by the German government in 1999. Net burdens (i.e., the overall reform burdens resulting from energy tax payments less reimbursements) as well as energy taxes refer to 2003 as the terminal year of the environmental tax reform which included annual discrete increases of energy tax rates. Employees of German industrial associations are taken from 1995 reflecting the fact that the political debate about an environmental tax reform in Germany has already reached its climax in the mid-1990s. We thereby intend to better represent the policy process leading to the design of the reform. For the same reason, price elasticities of energy use as well as production and employment levels are taken from this period, and estimates of Armington elasticities are based on time-series data ending in 1990. Due to limited data availability, information on market concentration is based on the year 2001. The time lag between the observation years for taxes and central independent variables assures that potential endogeneity problems (environmental taxation may for example affect energy demand) are attenuated (Kennedy 2003).[9]

An overview of all regression variables is provided in Table 2. Summary statistics for the variables are given in Table 3. The data underlying our econometric analysis is readily available upon request.

3.3 Econometric approach

For our regression analysis, one option is to estimate the coefficients for all three energy tax components within the German reform (electricity, gas and fuel oil tax) by ordinary least squares (OLS). In this case we would adopt a log-log multiple regression model, where Y_s denotes the dependent variable with s sectoral observations, X_{is} refer to the independent variables with associated coefficients β_i, α is a constant and ε_s is a disturbance term:

$$\ln Y_s = \alpha + \beta_1 \ln X_{1s} + \beta_2 \ln X_{2s} + \cdots + \beta_n \ln X_{ns} + \varepsilon_s \tag{13}$$

The slope coefficients β_i then measure the elasticity of Y with respect to X_i.

However, a potential problem for the interpretation of the separate OLS regressions arises as the three energy tax components form part of a joint environmental tax reform: the associated three tax equations might therefore be connected via correlations between the respective disturbance terms. We therefore decide to employ Seemingly Unrelated Regression Estimation (SURE—see Zellner 1962) as our econometric approach for the determinants of environmental taxation. SURE allows us to

[9] Note that the preferable approach to cope with endogeneity problems is an instrumental variable estimation, where an instrument variable (a new independent variable that is contemporaneously uncorrelated with the error term and preferably highly correlated with the original independent variable) substitutes the original independent variable. Our inferior lagged-variable approach is motivated by the lack of appropriate instrumental variables.

Table 2 Description of regression variables (see Sect. 3.2 on data sources)

Variable	Description
Dependent variables	
Electricity tax	Average effective tax rate on electricity use (€/MWh)
Gas tax	Average effective tax rate on gas use (€/MWh)
Oil tax	Average effective tax rate on fuel oil use (€/1000 l)
Net burden	Energy tax payments less reimbursements (million €)
Explanatory variables	
Lobby	Total number of representatives of industrial associations per sector
Electricity elasticity	Price elasticity of electricity demand
Gas elasticity	Price elasticity of gas demand
Oil elasticity	Price elasticity of fuel oil demand
Total energy elasticity	Price elasticity of total energy demand
Lobby_electricity	Interaction term (*Lobby* * *Electricity elasticity*)
Lobby_gas	Interaction term (*Lobby* * *Gas elasticity*)
Lobby_oil	Interaction term (*Lobby* * *Oil elasticity*)
Lobby_energy	Interaction term (*Lobby* * *Total energy elasticity*)
Electricity intensity	Electricity use per monetary unit of output (GWh/€)
Gas intensity	Gas use per monetary unit of output (GWh/€)
Oil intensity	Fuel oil use per monetary unit of output (1000 l/€)
Total energy intensity	Total energy use per monetary unit of output (GWh/€)
Employment	Employment level (in1000 employees)
Concentration	Herfindahl-Hirschman Index (HHI)
International exposure	Armington elasticity of substitution between imports and domestic goods

estimate the three individual energy tax equations as a set using a single regression, thereby accounting for contemporaneous correlation between the disturbance terms across equations (Kennedy 2003). As for the OLS option, we adopt a log-log regression specification for the SURE tax regression models.

For the (single) net burden regression the SURE approach is not eligible. Thus the net burden regression is invariably estimated by OLS. However, the log-log regression model cannot be applied in this case since the observed net burden is negative for some sectors. We therefore have to specify a lin-log model, where only the independent variables are logarithmized such that β_i measures the ratio between an absolute change in Y and a relative change in X_i. In this case, coefficients must be standardized (yielding so-called *Beta coefficients*) to accommodate a more transparent interpretation.

3.4 Regression results

All estimation results—the SURE coefficient estimates for the three energy tax regressions and the OLS estimates for the net burden regression (together with the respective goodness of fit)— are presented in Table 4.

Table 3 Summary statistics for regression variables

Variable	Obs.	Mean	SD	Min.	Max.
Dependent variables					
Electricity tax	42	5.57	3.83	1.31	19.91
Gas tax	42	0.61	0.31	0.32	1.61
Oil tax	42	7.73	3.82	4.05	20.19
Net burden	42	−30.36	68.49	−278.16	68.97
Explanatory variables					
Electricity elasticity	42	0.26	0.09	0.19	0.39
Lobby	42	49.50	67.09	0.00	350.00
Gas elasticity	42	0.62	0.15	0.10	0.82
Oil elasticity	42	0.58	0.18	0.10	0.89
Total energy elasticity	42	0.46	0.13	0.16	0.69
Electricity intensity	42	0.29	0.34	0.00	1.63
Gas intensity	42	0.47	0.74	0.00	3.23
Oil intensity	42	5.16	5.11	0.08	29.29
Total energy intensity	42	0.82	0.95	0.03	4.27
Employment	42	294.36	380.97	9.00	1,709.00
Concentration	36	62.87	84.63	2.80	357.65
International exposure	35	0.69	0.48	0.08	2.36

In our empirical estimations, we do not find a significant coefficient of the lobby variable in the tax or net burden equations. It appears that lobbying efforts standalone are not able to generate a regulatory design in favor of the better represented sectors. We therefore can't confirm the hypothesis that differentiated taxes are driven by interest group activities alone.

Our theoretical proposition derived in Sect. 2 stated that the effects of lobbying should be more pronounced in sectors with inelastic energy use. We can investigate this theoretical assertion empirically by the inclusion of a multiplicative interaction term between the number of lobby representatives and the price elasticity of energy demand. Our theoretical proposition implies a negative coefficient of the demand elasticity and a positive one of the interaction term in the energy tax equations. Our SURE and OLS estimation results support the theoretical predictions regarding the role of energy demand elasticities and their interaction with lobby power: In the gas and oil tax regression as well as in the net burden equation we observe significantly *negative* coefficients of energy demand elasticities.[10] In the same regression equations we find an (additional) significantly *positive* impact of the interaction term between the lobby variable and energy demand elasticities on the tax level: less elastic sectors with more powerful lobbies feature lower tax levels and net burdens than those with

[10] This result implies that sectors with less elastic energy demand are taxed at a higher level, corresponding to a standard Ramsey formula.

Table 4 Parameter estimation on the determinants of environmental taxation—SURE and OLS with robust standard errors

Explanatory variables	Dependent variable (model)			
	Electricity tax (log-linear, SURE)	Gas tax (log-linear, SURE)	Oil tax (log-linear, SURE)	Net burden (lin−log, OLS)
Lobby	0.0342	0.036	0.036	0.413
	(0.16)	(0.54)	(0.42)	(1.38)
Electricity elasticity	−0.363			
	(−0.75)			
Gas elasticity		−0.926**		
		(−2.57)		
Oil elasticity			−0.821*	
			(−1.79)	
Total energy elasticity				−1.359**
				(−2.34)
Lobby_electricity	0.106			
	(0.70)			
Lobby_gas		0.260***		
		(2.68)		
Lobby_oil			0.235**	
			(1.99)	
Lobby_energy				1.610 *
				(2.03)
Electricity intensity	−0.159***			
	(−3.83)			
Gas intensity		−0.035*		
		(−1.72)		
Oil intensity			0.004	
			(0.12)	
Total energy intensity				0.411**
				(2.69)
Employment	0.130**	0.134***	0.162***	−0.137
	(2.00)	(2.75)	(3.03)	(−0.88)
Market concentration	−0.115**	−0.053	−0.048	0.264
	(−2.32)	(−1.34)	(−1.02)	(1.71)
International exposure	−0.137	−0.251***	−0.266***	0.319
	(−1.43)	(−3.45)	(−3.33)	(1.62)
Constant	0.725	−1.431***	1.008**	−132.561
	(0.92)	(−3.64)	(1.98)	(−1.36)
Goodness of fit	$R^2 = 0.70$	$R^2 = 0.61$	$R^2 = 0.56$	$R^2 = 0.65$
Chi-square	$\chi^2 = 61.82$***	$\chi^2 = 51.87$***	$\chi^2 = 38.98$***	

Z-statistics in parentheses.
* (**, ***) indicates that the null hypothesis of the respective parameter being zero can be rejected at the 10 % (5 %, 1 %) level of significance (according to the corresponding two-tailed test)
OLS coefficients have been standardized (yielding so-called *Beta coefficients*)

weaker interest groups (and vice versa).[11] In other words, lobbying counteracts the negative stand-alone effect of energy demand elasticities on energy taxation and net burdens, thereby alleviating the sectoral burden of the environmental tax reform.[12]

Our empirical result suggests that German industries represented by stronger associations—in terms of political communication—were able to lobby for lower energy taxes *only* for inelastic sectors which are more exposed to regulation.[13] This finding is also in line with the general theoretical assessments on lobbying influence by Grossman and Helpman (2001) and Potters and Winden (1992). We conclude that for lobbying efforts to be effective, politically relevant arguments (such as strong incidence of environmental regulation) have to be brought forward by the interest group.

As to energy intensities, we observe significantly negative coefficients of the electricity and gas intensity in the respective tax regressions. According to our dataset, Germany's environmental tax reform discriminates in favor of energy-intensive sectors—a result that is consistent with the tax break regulations at the firm level. However, we identify a significantly positive effect of the total energy intensity on the net burden, suggesting that despite the tax break regulations, in overall terms more energy-intensive sectors are negatively affected by the reform. One reason is the revenue recycling scheme of the tax reform. Additional energy tax revenues are used to cut back the social security contributions by employers. As a consequence, sectors with higher energy intensities are less compensated than sectors with higher labor intensities.

Sectoral employment has a significantly positive effect on the tax rates for electricity, gas and oil. This indicates that the tax reform design has been less concerned on the tax-levying side about sectors with a larger working force since the latter are expected to be more than compensated through the recycling scheme. In fact, for the net burden of the reform as a dependent variable, we do not observe a significant effect: since sectors with high employment levels benefit from the environmental tax reform via reimbursements of the energy tax yield, the negative effect of taxation is compensated.

Next, we turn to the role of market concentration. According to Olson (1965), more concentrated industries should have a higher degree of interest organization and should therefore be more capable to put forward their political positions. This should also hold for arguments against environmental taxation, as in this case the tax incidence is concentrated on a smaller number of businesses. Our estimations partly confirm this prediction by showing a significantly negative coefficient of market concentration in the electricity tax equation, i.e. more concentrated industries face lower electricity taxes (see Table 4). This result for the electricity sector is in line with previous empirical studies testing Olson's theory, which confirmed that the industry's structure is an

11 This result can be deduced by taking the partial derivative of the tax rate w.r.t. the respective energy demand elasticity, yielding a sum of the (negative) coefficient of the energy demand elasticity and the (positive) coefficient of the interaction term multiplied by the lobby variable.

12 An alternative regression specification including an interaction term between the number of lobby representatives and the sectoral Armington elasticity does not yield significant estimation results for the respective coefficients.

13 Note that a potential endogeneity problem of lobby formation should be attenuated by our deliberate choice of observation years for lobby employees (1995) and tax rates (1999).

important determinant of political activity of firms (Masters and Keim 1986; Pittman 1988).

To investigate the impact of international trade exposure on Germany's environmental tax design, we use sector-specific elasticities of substitution between domestically produced goods and competing imports (so-called Armington elasticities) as a control variable. Unilateral energy taxation increases the price of domestically produced energy-intensive goods, which leads to a decline in domestic production as untaxed competing imports become relatively cheaper. The higher the Armington elasticities are, the stronger is—ceteris paribus—this substitution effect. Armington elasticities may, therefore, serve as an indirect measure for the relocation of domestic production facilities to abroad. In policy practice, relocation is a wide-spread argument of energy- and trade-intensive industries to claim exemption from unilateral environmental taxation (Böhringer and Rutherford 1997). In our estimations we find significantly negative coefficients of the Armington elasticity—both in the gas and oil tax regression. We conclude that international trade exposure is a significant determinant of Germany's environmental taxation—more exposed industries are taxed at a lower level.

4 Conclusions

In this paper, we have analyzed the political economy of energy tax differentiation across industries both on theoretical and empirical grounds. Based on a common-agency approach, our theoretical analysis has identified substantial effects of lobbying in particular for sectors with highly inelastic energy demand: on pure efficiency grounds, such sectors would be assigned high taxes as they are less distortionary than those in other sectors. In our political-economy framework, however, the associated high tax burden for sectors with inelastic energy demands implies strong lobbying incentives which in turn can translate into substantial tax-breaks for these sectors.

In the empirical analysis we have used sectoral data of Germany's environmental tax reform in order to test our theoretical propositions. A regression analysis based on OLS and seemingly unrelated regression estimation (SURE) underpins our theoretical results: industries exposed to environmental regulation are, when represented by more powerful associations (in terms of the number of lobby representatives), better able to communicate their interests and enforce lower energy taxes. Thus, interactions between lobby power and sectoral characteristics play an important role for the design of tax schemes. While industries with a less elastic energy demand may face higher energy taxes under the environmental tax reform, powerful lobbying is able to counteract this effect. Finally, the regression analysis provides evidence that—besides the efforts of lobby groups—also market concentration and international trade exposure of industries play a substantial role for energy tax differentiation.

Our combined theoretical and empirical analysis has explained differences in energy tax rates across sectors within a political economy framework. On the one hand, energy tax differentiation might increase the acceptability of environmental regulation. On the other hand, sectoral tax differentiation can substantially increase the economy-wide cost to achieve a given environmental goal. An explicit analysis of such interactions between political economy aspects and pure efficiency considerations provides an interesting direction for future research.

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Appendix

Derivation of condition (9)

Denoting the Lagrange multipliers for (1) and (2) by μ_1 and μ_2, and aggregate labor demand by $L = \sum_s l_s$, and using (5) and (6), we obtain the following first-order conditions from maximizing (8):

$$0 = \frac{\partial G}{\partial \sigma} = \sum_s (\lambda\kappa_s + 1) l_s + \bar{w}_e \frac{\partial L}{\partial \sigma} + \psi(\bar{w}_p - \bar{w}_e)\frac{\partial L}{\partial \sigma} - (\psi - \mu_2)\left[\sigma \frac{\partial L}{\partial \sigma} + L\right] \tag{14}$$

and

$$0 = \frac{\partial G}{\partial \tau_s} = -(\lambda\kappa_s + 1)e_s - \mu_1 \frac{\partial e_s}{\partial \tau_s} + (\psi - \mu_2)\left[\tau_s \frac{\partial e_s}{\partial \tau_s} + e_s\right]. \tag{15}$$

Conditions (14) and (15) determine the optimal differentiation of taxes.

Condition (14) can be rewritten as:

$$\begin{aligned} \psi - \mu_2 - 1 &= \lambda \sum\nolimits_s \kappa_s l_s / L + [\bar{w}_e + \psi(\bar{w}_p - \bar{w}_e) - (\psi - \mu_2)\sigma]\frac{\partial L}{\partial \sigma}/L \\ &= \lambda \sum\nolimits_s \kappa_s \gamma_s + [\bar{w}_e + \psi(\bar{w}_p - \bar{w}_e) - (\psi - \mu_2)\sigma]\varepsilon/(\bar{w}_p - \sigma) \end{aligned} \tag{16}$$

Here, $\varepsilon = \frac{\partial L}{\partial \sigma}\frac{\bar{w}_p - \sigma}{L}$ denotes the price elasticity of aggregate labor demand, and $\gamma_s = l_s/L$ is the fraction of labor in sector s.

Condition (15) is equivalent to condition (9) in Sect. 2.1 of our theoretical analysis:

$$\begin{aligned} 0 &= -(\lambda\kappa_s + 1) + \mu_1\eta_s/(\bar{z} + \tau_s) + (\psi - \mu_2)[1 - \eta_s\tau_s/(\bar{z} + \tau_s)] \\ \tau_s &= -\bar{z} + \frac{\mu_1 + (\psi - \mu_2)\bar{z}}{(\psi - \mu_2) - (\psi - \mu_2 - \lambda\kappa_s - 1)/\eta_s} \end{aligned} \tag{9}$$

where $\eta_s = (-\frac{\partial e_s}{\partial \tau_s}/e_s)(\bar{z} + \tau_s)$ denotes the price elasticity of energy demand in sector s.

Proof of Proposition While (i) follows immediately from condition (10), we show (ii) by studying the extreme cases in which (a) the regulator does not consider contributions

($\lambda = 0$), and (b) the regulator only considers lobby support but places no weight on social welfare ($\lambda \to \infty$).[14]

Case (a): If there is no political power of interest groups ($\lambda = 0$) then:

$$\psi - \mu_2 - 1 = [\bar{w}_e + \psi(\bar{w}_p - \bar{w}_e) - (\psi - \mu_2)\sigma]\varepsilon/(\bar{w}_p - \sigma) \tag{17}$$

$$\tau_s = -\bar{z} + \frac{\mu_1 + (\psi - \mu_2)\bar{z}}{(\psi - \mu_2) - (\psi - \mu_2 - 1)/\eta_s} \tag{18}$$

Since $\psi - \mu_2 - 1 > 0$,[15] and $\bar{z} > 0$, the numerator of the second term of (18) is positive and condition (18) implies that, ceteris paribus, less elastic energy demand leads to higher tax rates: tax rates will be differentiated because of a "tax yield" effect which corresponds to a standard Ramsey-formula.

Case (b): If the regulator maximizes lobby support ($\lambda \to \infty$) only, the first-order conditions can be rewritten as (using a normalization of μ_1 and μ_2):

$$-\mu_2(1 + \sigma\varepsilon/(\bar{w}_p - \sigma)) = \sum\nolimits_s \kappa_s \gamma_s \tag{19}$$

$$\tau_s = -\bar{z} + \frac{\mu_1 - \mu_2\bar{z}}{-\mu_2 + (\mu_2 + \kappa_s)/\eta_s}. \tag{20}$$

Condition (19) implies that $0 < -\mu_2 < \sum_s \kappa_s \gamma_s$ (where the right-hand side represents a labor-weighted average of lobbying power). As a consequence, the numerator in condition (20") is positive ($\bar{z} > 0$). With this, (20") implies that sectors with large κ_s (i.e. $\mu_2 + \kappa_s > 0$) will, ceteris paribus, face a smaller energy tax if they have less elastic energy demands. This completes the proof. □

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[14] Due to continuity, the qualitative relationships for $\lambda = 0$ extend to sufficiently small λ, while sufficiently large λ qualitatively correspond to $\lambda \to \infty$.

[15] This is trivial for the case where $\mu_2 < 0$. If $\mu_2 > 0$, condition (11') implies the positive sign of $(\psi - \mu_2 - 1 > 0)$ as the wedge between wages received by employees and the costs of labor faced by employers is positive, i.e. $\bar{w}_p - \bar{w}_e > \sigma$.

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