WIFO

ÖSTERREICHISCHES INSTITUT
FÜR WIRTSCHAFTSFORSCHUNG

WORKING PAPERS

Energy and Carbon Taxes in the EU

Empirical Evidence with Focus on the Transport Sector

Claudia Kettner-Marx,
Daniela Kletzan-Slamanig

555/2018

ÖSTERREICHISCHES INSTITUT FÜR WIRTSCHAFTSFORSCHUNG
AUSTRIAN INSTITUTE OF ECONOMIC RESEARCH

Energy and Carbon Taxes in the EU

Empirical Evidence with Focus on the Transport Sector

Claudia Kettner-Marx, Daniela Kletzan-Slamanig

WIFO Working Papers, No. 555

February 2018

Abstract

This paper provides an overview of energy and (implicit) CO_2 taxation in the EU member countries. Against the background of the EU energy taxation directives, energy and implicit CO_2 tax rates in the EU countries are discussed, focussing on taxation in the transport sector as a major non-ETS emitter. Empirical evidence on the impact of energy and carbon taxes on energy use and emissions is presented and the economic and distributional effects of energy and carbon taxes are then discussed. Research on energy price elasticities suggests that energy and carbon taxation can make a significant contribution towards achieving emission reductions, particularly in the transport sector where greenhouse gas emissions continue to be on the rise in the EU. Evidence on the economic impacts of energy and carbon taxes furthermore shows that a double divided can be achieved. With respect to the distributional impacts of carbon and energy taxes evidence is, however, mixed. While empirical studies generally negate regressive effects for taxes on transport fuels, energy and carbon taxes on heating fuels tend to be found regressive.

E-mail addresses: claudia.kettner@wifo.ac.at, daniela.kletzan-slamanig@wifo.ac.at
2018/062/W/8815

Medieninhaber (Verleger), Hersteller: Österreichisches Institut für Wirtschaftsforschung • 1030 Wien, Arsenal, Objekt 20 • Tel. (43 1) 798 26 01-0 • Fax (43 1) 798 93 86 • http://www.wifo.ac.at/ • Verlags- und Herstellungsort: Wien
Die Working Papers geben nicht notwendigerweise die Meinung des WIFO wieder
Kostenloser Download: http://www.wifo.ac.at/wwa/pubid/60972

Energy and Carbon Taxes in the EU: Empirical Evidence with Focus on the Transport Sector

Claudia Kettner and Daniela Kletzan-Slamanig

February 2018

Abstract

This paper provides an overview of energy and (implicit) CO_2 taxation in the EU Member States. Against the background of the EU energy taxation directives, energy and implicit CO_2 tax rates in the EU Member States are discussed, focussing on taxation in the transport sector as a major non-ETS emitter. Empirical evidence on the impact of energy and carbon taxes on energy use and emissions is presented and the economic and distributional effects of energy and carbon taxes are then discussed.

Research on energy price elasticities suggests that energy and carbon taxation can make a significant contribution towards achieving emission reductions, particularly in the transport sector where greenhouse gas emissions continue to be on the rise in the EU. Evidence on the economic impacts of energy and carbon taxes furthermore shows that a double divided can be achieved. With respect to the distributional impacts of carbon and energy taxes evidence is, however, mixed. While empirical studies generally negate regressive effects for taxes on transport fuels, energy and carbon taxes on heating fuels tend to be found regressive.

Keywords

Energy taxation, carbon taxation, EU Member States, environmental impact, macro-economic effects, distributional effects

JEL codes

Q48, Q54, Q58

1 Introduction

Climate change is one of the big challenges humanity is facing. A transition of the global energy system towards sustainability with dramatically reduced greenhouse gas (GHG) emissions is required in order to limit climate change. Especially after the adoption of the Kyoto Protocol in 1997, climate change policies have been increasingly introduced in industrialised and increasingly also in emerging countries, with the EU taking a leading role. The range of potential instruments for promoting GHG emission reductions includes performance standards, technology standards as well as market-based approaches like energy or emission (carbon) taxes and emission trading systems. Economic literature generally argues in favour of market-based instruments since they ensure compliance at the least cost to society by offering flexibility in the choice of abatement measures and their timing. Moreover, taxes and auctioned emission permits raise revenues that in turn can be used to subsidise other abatement measures and R&D activities or to mitigate the negative distributional effects.

For large emitters from industry and energy supply the EU has established the European Emission Trading System (EU ETS) in 2005, which covers about 45 percent of total GHG emissions in the EU[1]. Since transaction and monitoring costs would be excessive otherwise, the system is applied to large point emitters only. Other emission sources like transport, households and small businesses are, up to now, subject to national energy / carbon taxation which varies substantially between Member States.

Member States have been levying energy taxes prior to the introduction of the EU ETS. These energy taxes have, however, been introduced mainly to raise revenues rather than to pursue environmental targets like reducing GHG emissions or energy use. Even in cases in which an ecological tax reform has been implemented, i.e. a shift of taxes from labour to environment and resource use, the definition of the level of tax rates has been determined by political feasibility and does not consistently reflect the various energy sources' carbon content (e.g. Böhringer and Schwager 2002). Thus, in most cases taxation does not correspond to the theoretical concept of optimal (uniform) energy or carbon taxes.

This paper provides an overview of energy and (implicit) CO_2 taxation in the EU Member States. Against the background of the EU energy taxation directives, energy and implicit CO_2 tax rates in the EU Member States are discussed (section 2). Particular emphasis is then put on taxation in the transport sector (section 3), since this sector showed an increase of CO_2 emissions by 17 per cent during the past 25 years (from from 758 Mt in

[1] The EC had initially been in favour of a carbon tax that, however, could not be adopted due to the resistance of some Member States and the requirement of unanimity in fiscal environmental policies; eventually an ETS was set up, partly due to lobbying activities of the industry (e.g. Skjærseth and Wettestad 2008). Since its start in 2005, many reforms within the design of the EU ETS have been introduced that should help generate a stable and significant price signal for low-carbon investment.

1990 to 887 Mt CO_2 in 2015) and now accounts for more than 20 per cent of the EU's greenhouse gas emissions[2]. In section 4 empirical evidence on the impact of energy and carbon taxes on energy use and emissions is presented, and the macroeconomic and distributional effects of energy and carbon taxes are then discussed in section 5, since potential negative effects of carbon taxes on economic growth, employment and income distribution are frequently brought up when discussing their implementation. Section 6 concludes.

2 Energy Taxation in EU Member States

The first energy taxes were levied in EU Member States about a century ago: Denmark was the first Member State to introduce taxes on transport fuels in 1917, followed by Sweden in 1924 (see Speck 2008)[3]. Since then, energy taxes have been implemented in all Member States. As of 2016, energy taxes accounted for 4.7 per cent of the total tax revenues of the EU 28 and for 1.9 per cent of GDP respectively[4].

Energy taxes were originally introduced to raise tax revenues. In the course of the oil crisis in the 1970s energy security aspects were, however, considered in the design of the taxes, aiming at incentivising a more efficient use of energy. During the 1980s environmental principles have been introduced in energy taxation, and in the 1990s climate change considerations finally were taken up in Member States' energy taxation.

In Council Directive 92/82/EEC the EU established minimum excise duties on mineral oils used as propellants or for heating. For different application areas and energy sources, different minimum excise duties applied: For leaded and unleaded petrol the minimum rates were ECU 10.2 per GJ and ECU 8.7 per GJ[5], respectively, while the minimum rate for gasoil when used as propellant was ECU 6.8 per GJ[6]. For gasoil serving heating purposes, the minimum rate was set at ECU 0.6 per GJ[7]. Fuels used for heating purposes were generally subject to lower tax rates than transport fuels.

The lower tax rates for diesel as compared to petrol were motivated by competitiveness concerns, i.e. the preferential treatment of freight transport. This tax spread, though,

---

2 UNFCCC (2017), National Inventory Reports 2017.

3 Taxes on energy consumption for non-transport purposes were first introduced in Sweden in 1957.

4 The contributions of energy taxes to total tax revenues vary, however, considerably between Member States ranging between 3.03 per cent in Belgium and 9.85 per cent in Latvia.

5 For Luxembourg provisional lower tax rates for the period 2003 to 2004 were allowed.

6 For Luxembourg and Greece reduced minimum rates are applied. For industrial applications and heating purposes a lower minimum rate of ECU 18 per 1,000 litres was agreed on (with respect to heating additional exceptions for Member States in which previously no excise duties had been levied on heating oil were provided for).

7 For Member States that had not implemented taxes of gasoil for heating purposes, initially lower minimum tax rates applied.

also contributed to a growing share of diesel cars in the EU. The Commission hence strived for an alignment of the minimum tax rates for petrol and private diesel consumption in 2002. The proposed changes in regulation, however, were not adopted due to resistance from some Member States and the requirement of unanimity in taxation issues.

The EU framework for energy taxation was then revised and extended in 2003 with Directive 2003/96/EC. This directive provides new minimum tax rates for propellants, heating fuels and electricity[8]. With respect to natural gas, coal and coke used as heating fuels as well as electricity differentiated minimum tax rates were defined for business and non-business applications. Moreover, a stepwise increase of the minimum excise duties for gasoil and kerosene was provided for. The minimum excise duties for petrol were increased by 25 per cent as compared to Directive 92/82/EC. For diesel the minimum rates were set at EUR 8.4 per GJ until 2009, increasing to EUR 9.2 per GJ in 2010.

The aim of the energy taxation directives was to define minimum tax rates for the different energy sources and application areas. Today, effective excise duties levied on fossil fuels and electricity correspond to these minima in some Member States, while they are considerably above these levels in others. Table 1 gives an overview of the energy tax rates implemented for the different energy sources and application areas in the 28 EU Member States as well as the corresponding minimum excise duties as of January 2017. As also provided for in Directive 2003/96/EC, the highest taxes are levied on fuels used as propellant, i.e. on petrol and diesel as well as on gas. Minimum tax rates for heating fuels amount to 1 to 11 percent of the minimum tax rate for petrol and are highest for gasoil. While for the other heating fuels as well as for electricity the tax rates for non-business use are twice as high as for business purposes, the minimum tax rate of gasoil is identical for both application areas and with EUR 0.58 per GJ higher than the tax rates for the other energy sources.

[8] It is to be noted that especially with respect to electricity a number of exemptions existed for different applications such as chemicals reduction or in electrolytic and metallurgical processes and that in Annex 2 of Council Directive 2003/96/EC a comprehensive list for diverse national exceptions for different application areas and / or fuels was included.

Table 1. Energy Tax Rates in EU Member States in EUR per GJ as of January 2017

	Coal - Heating Business use	Coal - Heating Non-business use	Petrol	Gasoil - Propellant	Gasoil - Heating Business use	Gasoil - Heating Non-business use	Gas - Propellant	Gas - Heating Business use	Gas - Heating Non-business use	Electricity - Business use	Electricity - Non-business use
AT	1.70	1.70	15.20	11.43	3.14	3.14		1.66	1.66	4.17	4.17
BE	0.41	0.41	19.16	14.34	0.50	0.50		0.28	0.00	0.83	0.54
BG	0.31	0.31	11.07	9.19	9.19	9.19	0.43	0.31	0.00	0.28	0.00
CY	0.00	0.31	14.60	12.52	3.47	3.47	2.60	2.60	2.60	1.39	1.39
CZ	0.31	0.31	14.49	11.27	11.27	11.27	0.70	0.31	0.31	0.29	0.29
DE	0.17	0.33	20.19	13.30	1.49	1.92	11.46	8.67	8.76	4.27	5.70
DK	9.62	9.62	20.19	11.67	9.11	9.11	11.55	8.74	8.74	0.15	33.97
EE	0.93	0.93	14.18	12.46	12.46	12.46		0.89	0.89	1.24	1.24
ES	0.15	0.65	13.42	9.21	2.36	2.36	1.15	0.15	0.65	1.42	1.42
FI	7.49	7.49	21.42	14.76	6.36	6.36	5.17	5.17	5.17	1.95	6.26
FR	2.78	2.78	19.84	14.76	3.31	3.31	1.53	1.63	1.63	6.26	6.26
GR	0.30	0.30	21.34	11.40	11.40	11.40	0.00	0.60	0.30	1.39	0.61
HR	0.31	0.31	15.68	14.74	1.57	1.57	0.00	0.15	0.30	0.14	0.27
HU	0.30	0.30	12.12	10.41	10.41	10.41	2.67	0.30	0.30	0.28	0.28
IE	1.89	1.89	17.92	13.32	2.84	2.84	2.60	1.03	1.03	0.14	0.28
IT	0.16	0.32	22.21	17.17	11.22	11.22	0.09	0.34	3.89	2.30	6.31
LT	0.15	0.30	13.24	9.18	0.59	0.59	6.56	0.15	0.30	0.14	0.28
LU	5.00	0.30	14.13	9.36	0.28	0.28	0.00	0.30	1.08	0.14	0.28
LV	0.35	0.35	13.29	9.48	1.09	1.09	2.67	0.46	0.46	0.28	0.28
MT	0.30	0.30	16.75	13.13	6.46	6.46		0.84	0.84	0.42	0.42
NL	0.54	0.54	23.47	13.48	13.48	13.48	4.57	2.55	7.16	11.43	27.99
PL	0.30	0.30	12.40	9.45	6.45	6.45	2.48	0.30	0.30	1.30	1.30
PT	0.59	0.59	18.83	11.18	9.53	9.53	3.13	0.59	0.59	0.28	0.28
RO	0.16	0.32	11.35	9.49	9.49	9.49	2.79	0.18	0.34	0.15	0.30
SE	12.89	12.89	20.57	17.19	8.36	12.02	6.40	5.87	8.89	0.15	8.66
SI	1.86	1.86	16.75	13.10	5.63	5.63	3.45	1.42	1.42	0.85	0.85
SK	0.31	1.00	16.24	10.49	10.49	10.49	2.60	0.37	0.37	0.37	0.00
UK	0.00	0.00	20.23	18.46	3.55	3.55	5.67	0.61	0.61	0.00	0.00
EU MED*	0.15	0.30	10.95	9.18	0.58	0.58	2.60	1.15	0.30	0.14	0.28

* Minimum Excise Duty

Note: Tax rates as displayed in the EU Excise Duty Tables (January 2017); country-specific exemptions not included.

Converting the (minimum) energy tax rates into a CO_2 price signal based on the fuels' carbon content delivers the implicit carbon tax rates levied in the EU Member States as of January 2017 (Table 2)[9]. With respect to propellants, implicit carbon minimum tax rates are EUR 128 per tonne CO_2 for diesel and EUR 140 for petrol. For coal used as heating fuel, in contrast, minimum tax rates are EUR 1.6 per tonne CO_2 for business use and EUR 3.2 per tonne CO_2 for non-business use, respectively. Since the CO_2 emission factors of the individual energy sources are assumed to be identical for all Member States (except for electricity), the implicit carbon tax rates implemented in the Member States also diverge strongly between application area and energy source. This spread of excise duties is in stark contrast to the economic theory on carbon pricing, postulating uniform taxation of emissions as a prerequisite for efficient regulation.

[9] Energy tax rates are converted into implicit carbon tax rates using emission factors from UNFCCC (2017).

Table 2. Implicit CO_2 Tax Rates in EU Member States in EUR per t CO_2 as of January 2017

	Coal - Heating Business use	Coal - Heating Non-business use	Petrol	Gasoil - Propellant	Gasoil - Heating Business use	Gasoil - Heating Non-business use	Gas - Propellant	Gas - Heating Business use	Gas - Heating Non-business use	Electricity - Business use	Electricity - Non-business use
AT	18.09	18.09	194.85	146.56	40.30	40.30		30.74	30.74	99.24	99.24
BE	4.41	4.41	245.61	183.79	6.40	6.40		5.13	0.00	11.69	7.50
BG	3.30	3.30	141.89	117.78	117.78	117.78	7.96	5.74	0.00	2.89	0.00
CY	0.00	3.30	187.23	160.47	44.48	44.48	48.15	48.15	48.15	17.73	17.73
CZ	3.30	3.30	185.74	144.51	144.51	144.51	12.96	5.74	5.74	3.17	3.17
DE	1.81	3.51	258.81	170.47	19.08	24.55	212.22	160.56	162.22	50.36	67.17
DK	102.29	102.29	258.81	149.56	116.80	116.80	213.95	161.83	161.83	2.68	606.14
EE	9.89	9.89	181.75	159.76	159.76	159.76		16.48	16.48		
ES	1.60	6.91	172.10	118.03	30.21	30.21	21.30	2.78	12.04	17.28	17.28
FI	79.68	79.68	274.59	189.25	81.55	81.55	95.74	95.74	95.74	34.85	111.68
FR	29.57	29.57	254.34	189.25	42.40	42.40	28.33	30.19	30.19	93.07	93.07
GR	3.19	3.19	273.61	146.21	146.21	146.21	0.00	11.11	5.56	13.01	5.73
HR	3.26	3.26	201.03	189.00	20.10	20.10	0.00	2.78	5.55	1.81	3.62
HU	3.19	3.19	155.37	133.47	133.47	133.47	49.49	5.62	5.62	3.82	3.82
IE	20.11	20.11	229.72	170.81	36.47	36.47	48.15	19.07	19.07	1.86	3.72
IT	1.70	3.40	284.71	220.17	143.79	143.79	1.67	6.30	71.94	34.54	94.78
LT	1.60	3.19	169.81	117.68	7.54	7.54	121.48	2.78	5.56	4.08	7.93
LU	53.19	3.19	181.10	120.06	3.57	3.57	0.00	5.49	20.00	2.62	5.25
LV	3.72	3.72	170.42	121.60	13.95	13.95	49.44	8.52	8.52	7.44	7.44
MT	3.19	3.19	214.74	168.32	82.76	82.76		15.56	15.56	5.42	5.42
NL	5.74	5.74	300.93	172.76	172.76	172.76	84.63	47.22	132.59	156.43	383.05
PL	3.19	3.19	158.93	121.19	82.73	82.73	45.93	5.56	5.56	13.87	13.87
PT	6.28	6.28	241.37	143.36	122.17	122.17	57.96	10.93	10.93	3.49	3.49
RO	1.70	3.40	145.47	121.63	121.63	121.63	51.67	3.33	6.30	1.94	3.85
SE	137.13	137.13	263.70	220.35	107.15	154.04	118.52	108.70	164.63	4.80	282.00
SI	19.79	19.79	214.69	167.95	72.19	72.19	63.93	26.33	26.33	9.08	9.08
SK	3.30	10.64	208.14	134.51	134.51	134.51	48.15	6.85	6.85	6.20	0.00
UK	0.00	0.00	259.41	236.66	45.50	45.50	105.00	11.37	11.37	0.00	0.00
EU MED*	1.60	3.19	140.32	117.68	7.49	7.49	48.15	21.30	5.56	1.77	3.55

* Minimum Excise Duty

Note: Implicit CO_2 tax rates using UNFCCC emission factors and energy tax rates as displayed in the EU Excise Duty Tables (January 2017); country-specific exemptions not included.

3 Fuel taxation in the transport sector

In this section we focus on energy and carbon taxation in transport, since emissions from this sector have been continuously increasing since 1990 and it currently accounts for a major part (36 per cent) of non-ETS emissions and more than 20 per cent of the EU's total greenhouse gas emissions respectively[10].Figure 1 illustrates petrol and diesel tax rates in the EU 28 as of January 2017. Petrol tax rates range between EUR 11.1 per GJ in Bulgaria and EUR 23.5 per GJ in the Netherlands; diesel tax rates are in the range of the minimum excise duty of EUR 9.2 per GJ in Bulgaria, Lithuania and Spain and EUR 18.5 per GJ in the United Kingdom. Measured in EUR per GJ, petrol tax rates exceed diesel rates in all Member States by up to 87 per cent (Greece). It has to be noted, however, that in the UK the tax rate per litre is identical for petrol and diesel, although this

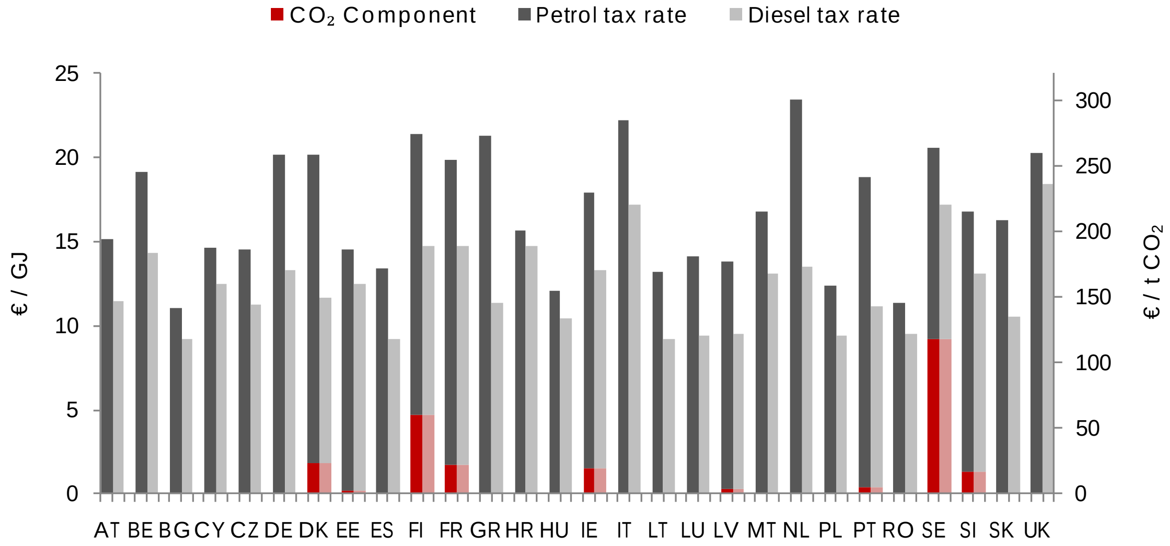
[10] UNFCCC (2017), National Inventory Reports 2017.

ultimately implies again a higher petrol tax rate per unit of energy due to its lower energy content compared to diesel[11]. In the majority of the Member States (i.e. 20 out of 28 countries), excise duties on diesel have meanwhile risen more strongly than those on petrol in the period 1995 to 2017. In constant terms, however, petrol tax rates declined in 15 Member States over the past 12 years.

In relation to the CO_2 content, energy tax rates translate into an implicit CO_2 tax rate of EUR 142–301 per tonne for petrol and EUR 118–237 per tonne for diesel, respectively, in the EU Member States as of January 2017.

An explicit carbon tax for the transport sector so far has only been introduced in ten Member States: Denmark, Estonia, Finland, France, Ireland, Latvia, Portugal, Slovenia, Sweden and Poland. Yet, in most of these countries the CO_2 tax accounts for only a small part of the overall tax rate on energy and is well below EUR 10 per tonne. Notable exceptions in this regard are Sweden, where the carbon component has increased to EUR 118 per tonne CO_2, and Finland with a CO_2 component of EUR 62 per tonne in 2017.

Figure 1. Petrol and diesel tax rates in EU Member States as of January 2017



Source: Own calculations based on the EC Excise Duty Tables January 2017.

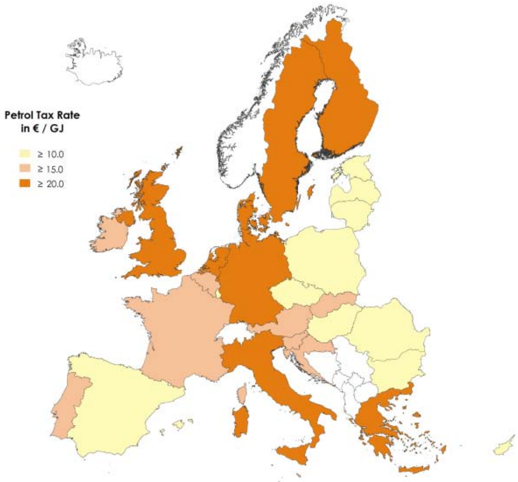
In the discussions about energy and carbon taxation Nordic countries such as Sweden, Finland, Denmark or the Netherlands are often referred to as front-runner countries. While Sweden and Finland are among the leading countries in the world in terms of carbon taxation, with respect to energy taxes this view neglects differences in purchasing power between countries. After correcting for differences in purchasing power, especially

[11] One litre of diesel delivers 19.6 GJ of energy compared to 17.6 GJ for petrol.

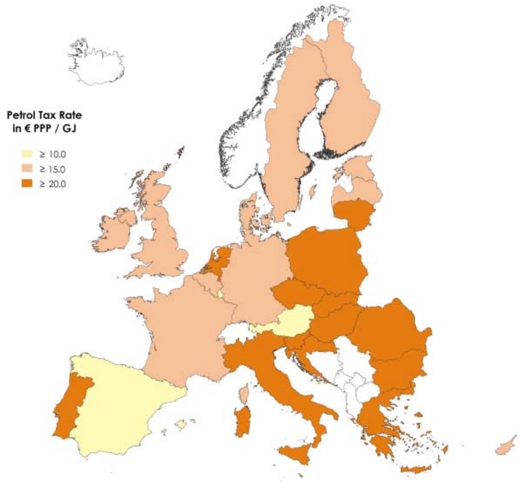
regarding petrol Greece and the Eastern Member States exhibit the highest tax rates (Figure 2): Petrol tax rates in EUR PPP are highest in Greece (EUR PPP 23.7 per GJ), followed by Slovakia (EUR PPP 23.6 per GJ), Croatia (EUR PPP 23.3 per GJ) and Poland (EUR PPP 21.7 per GJ). The lowest petrol tax rates corrected for purchasing power differences are applied in Luxembourg (EUR PPP 10.6 per GJ), Austria (EUR PPP 12.4 per GJ) and Spain (EUR PPP 14.3 per GJ). With regard to diesel tax rates, similar patterns can be detected. Diesel tax rates are highest in Croatia (EUR PPP 21.1 per GJ), followed by Bulgaria (EUR PPP 18.3 per GJ) and Romania (EUR PPP 17.6 per GJ). The lowest tax rates after controlling for differences in purchasing power are found for Luxembourg (EUR PPP 7 per GJ), Denmark (EUR PPP 8.3 per GJ) and Austria (EUR PPP 9.4 per GJ).

Figure 2. Petrol and diesel tax rates in EU Member States as of January 2017

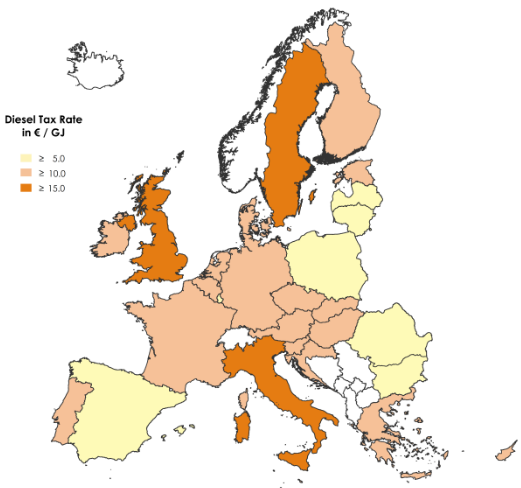
(a) Petrol tax rate in EUR per GJ



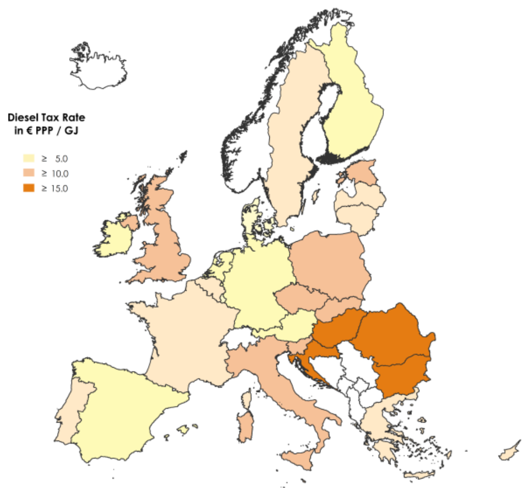
(b) Petrol tax rate in EUR PPP per GJ



(c) Diesel tax rate in EUR per GJ



(d) Diesel tax rate in EUR PPP per GJ

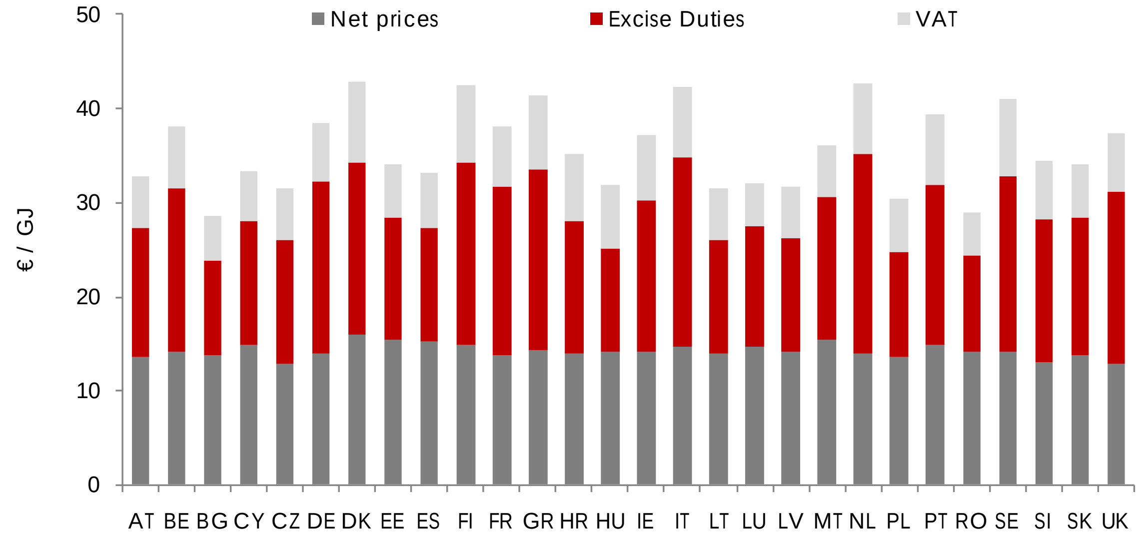


Source: Own calculations based on the EC Excise Duty Tables January 2017 and Eurostat.

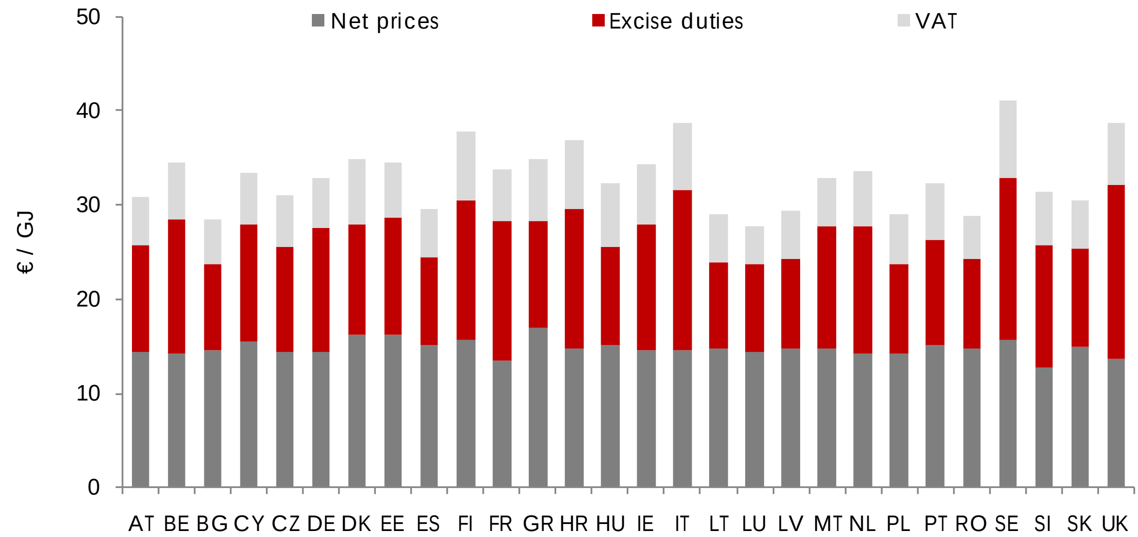
Energy and carbon taxation aim at establishing a price signal incentivising reductions in energy consumption and CO_2 emissions. Yet, tax rates are only one component of gross fuel prices and consumers will ultimately respond to (changes in) these prices instead of tax rates. Examining the structure of gross diesel and petrol prices in the EU 28 (Figure 3) reveals, however, that the major part of the variation in gross prices between Member States reflects differences in the excise duties on energy. Moreover, changes in energy tax rates on average accounted for 60 per cent of the price increases in the EU Member States in the period 2007 to 2017.

Figure 3. *Structure of gross fuel prices in EU Member States as of January 2017*

(a) Gross petrol prices in EUR per GJ



(b) Gross diesel prices in EUR per GJ



Source: Own calculations based on the EC Excise Duty Tables January 2017 and the Weekly Oil Bulletin 2017.

4 Impact of price signals on emissions

According to economic theory energy and carbon taxes can internalise negative environmental externalities by establishing a price signal that incentivises energy and emission reductions. This section starts out with a review of the available literature on environmental effects related to carbon taxes. This issue is closely linked to the discussions about the price elasticities of energy demand, since CO_2 emissions are directly proportional to fossil fuel use. Then energy price elasticities for the transport sector are estimated for a panel of EU Member States based on the database set up in the CATs project.

4.1 Literature review of the environmental effects of carbon taxes

The empirical evidence on energy price elasticities in EU Member States is scarce, also for the front-runner countries in terms of carbon taxation like Sweden and Finland.

Only few studies on the emission impact of the Swedish CO_2 tax are available. For the year 1994, studies by the Swedish Energy Agency NUTEK and the Swedish Environmental Protection Agency each estimated a 3 to 5 per cent emission reduction due to the implementation of the CO_2 tax (Anderson 2004). Enevoldsen et al. (2007) estimated an energy price elasticity of -0.44 in the period 1991 to 2001. Brännlund et al. (2014) focused on the Swedish industry and analysed its environmental performance at the firm level and the effectiveness of environmental policy between 1990 and 2004. Their analysis shows that environmental performance has improved in all the sectors and suggests decoupling of output production growth and CO_2 emissions. The results indicate that firms' carbon intensities responds to "changes in the CO_2 tax and fossil fuel price, but are more sensitive to the tax" (Brännlund et al., 2014, p. 850).

According to Sairinen (2012), the analysis of a government working group on environmental taxation found that carbon emissions in Finland were reduced by more than 7 per cent in the period 1990 to 1998 due to CO_2 and energy taxation.

Infras and Ecologic (2007) report that the CO_2 tax was expected to contribute 5 per cent to the Danish emission reduction target of -20 per cent by 2005. The Danish Environmental Protection Agency estimated an emission reduction of 24 per cent in the period 1990 to 2011 compared to a business as usual scenario (Speck et al. 2006). Bjorner and Jensen (2002) showed that energy price elasticities in Denmark depend on the level of the energy price. They estimated the average energy price elasticity at -0.44, for energy-intensive companies at -0.2, and at -0.7 for the remaining industry. Enevoldsen et al. (2007) obtained similar results with an energy price elasticity of -0.38 for the Danish industry in the period 1991 to 2001.

4.2 Energy Price Elasticities for Motorised Individual Transport in the EU

Methodological approach and data sources

In order to obtain initial estimates on energy price elasticities for individual transport in the EU, we use a fixed effects model. The fixed effects model is chosen to control for possible endogenous characteristics of the individual Member States, i.e. characteristics that do not change (or change very little) over time such as unobservable geographic characteristics.

Equations (1) and (2) describe the fixed effects models to estimate petrol and diesel price elasticities, respectively:

$$\ln CO2\_P_{it} = \alpha_i + \ln Y_{it} + lnEP\_P_{it} + lnS\_P_{it} + u_{it} \quad (1)$$

$$ln\, CO2\_D_{it} = \alpha_i + ln\, Y_{it} + lnEP\_D_{it} + lnS\_D_{it} + u_{it} \quad (2)$$

$CO2\_P_{it}$ and $CO2\_D_{it}$ denote CO_2 emissions of petrol (P) and diesel (D) cars per capita and Y_{it} denotes GDP per capita in constant 2010 EUR. EP_P_{it} and EP_D_{it} give gross petrol and diesel prices (in 2010 EUR) and S_P_{it} and S_D_{it} give the share of petrol and diesel cars in the total car stock, respectively. All the terms are represented in natural logs to capture growth rates. The coefficient α_i denotes the individual effect (or heterogeneity) for each Member State; u_{it} is the error term.

The following data sources are used for the analysis: Data on cars' CO_2 emissions as well as on the car stock are from the Odyssee Database; GDP data are from Eurostat. Gross petrol and diesel prices are taken from the Weekly Oil Bulletin. While data availability is excellent for recent years, for the Eastern European Member States that accessed the EU in the 2000s information for the period prior to the accession is highly incomplete. The database used for this analysis hence only covers the period 2004 to 2015. Moreover, six New Member States had to be excluded from the analysis since further data were missing[12].

Results

Table 3 summarises the regression results. The signs of all coefficients are as expected. The elasticity of CO_2 emissions per capita with respect to GDP per capita is 0.23 for petrol and 0.64 for diesel. An increase in fuel prices as expected reduces carbon emissions; the price elasticity is –0.31 for petrol and –0.16 for diesel. Shifts in the car stock towards petrol or diesel cars imply an increase in the respective emissions per capita. Overall, the price elasticities from this analysis are in the range of those reported in the literature and suggest that establishing a price signal via energy or carbon taxation can contribute to reducing greenhouse gas emissions from the transport sector.

12 Bulgaria, Croatia, Estonia, Malta, Lithuania and Romania.

Table 3. Estimation results

	ln CO_2_P	ln CO_2_D
ln Y	0.229***	0.639***
	(0.000)	(0.000)
ln EP_P	-0.308***	
	(0.000)	
ln EP_D		-0.155**
		-(0.005)
ln S_P	1.435***	
	(0.000)	
ln S_D		0.204***
		(0.000)
cons	-10.61***	-9.858***
	(0.000)	(0.000)
N	264	264
F	581.3	63.71
r^2	0.879	0.444

p-values in parentheses.

5 Economic and distributional impacts of carbon taxes

Potential negative effects of carbon taxes on economic growth, employment and income distribution are frequently brought up when discussing their implementation. In this section, therefore, existing empirical evidence on the economic and distributional impacts of carbon taxes in the EU Member States is reviewed and briefly presented. Provided the relevant information is available, the literature review focuses on the EU Member States that so far are being the front-runners in terms of carbon taxation: Sweden, Finland and Denmark.

Naturally, it is difficult to disentangle the effects of carbon taxes from other policy instruments. In the Nordic countries, carbon taxes have generally been implemented as part of more comprehensive environmental tax reforms (see e.g. IEEP 2013; Weishaar 2018). The economic impacts, therefore, have been analysed for the whole environmental tax reform instead of the carbon tax. Moreover, since carbon taxes in EU Member States constitute a part of energy taxation, the assessment of the distributional impacts focuses more on energy taxes in general.

5.1 Macroeconomic impacts of carbon taxes

For Denmark, IEEP (2013) notes that the Danish Ministry of Finance found an overall small but positive impact of the environmental tax reform on economic growth (0.3 per cent of GDP in the period 1990 to 1995). Also the COMETR study (Andersen et al. 2007) found positive economic effects of the environmental tax reform on GDP for Denmark as well as an annual increase in employment of about 0.5 per cent compared to the baseline in the period 1994 to 2012. According to Infras and Ecologic (2007), in contrast, only the short-term effect was slightly positive, while the mid-term effect (five years after introduction) was negative, although the magnitude was negligible.

According to COMETR (Andersen et al. 2007) the environmental tax reform in Finland resulted in an average yearly increase in GDP of 0.5 per cent for the period 1994 to 2002 compared to a baseline scenario. Especially short-term effects on GDP are positive, since reduced energy demand improves the country's trade balance due to reduced fuel imports. In Sweden employment was found to be increasing due to the environmental tax reform in spite of recycling the revenues via an income tax reduction and instead of a reduction of social security contributions; with respect to GDP the study estimates a long-term annual increase of about 0.5 per cent compared to a business as usual scenario.

In the last decades there has been a lively discussion in economic literature regarding the concept of a double dividend, i.e. the potential for positive economic effects in addition to environmental improvements that could be generated by environmental taxation. Key to the realisation of positive economic effects is revenue neutrality. The environmental tax revenues offer the opportunity to lower other distortionary taxes, e.g. on labour, thus altering relative input prices and contributing to increased labour demand. This is also confirmed by the research discussed above.

5.2 Distributional impacts of energy and carbon taxes

The empirical evidence on the distributional impacts of energy and carbon taxes suggests that the distributional effects vary between energy sources and indicators used[13].

A recent study by Flues and Thomas (2015), for instance, investigates the distributional effects of energy taxes in 21 OECD countries. The authors show that taxes on transport fuels on an expenditure basis are not regressive overall. One explanation is that households in lower expenditure deciles are less likely to possess a car, hence consume less transport fuels. In some of the 21 countries, taxes on transport fuels are found to be regressive both on an expenditure and an income basis, while in others the effects are more proportional or imply the highest burden for middle expenditure deciles. In contrast, with respect to heating, energy taxes all in all tend to be moderately regressive and taxes on electricity tend to be more regressive than taxes on heating fuels. In the study by Flues and Thomas, Finland is the only EU Member State with substantial carbon taxes on energy consumption that is included. The results for Finland are in line with the overall findings: With respect to transport fuels, the proportion of taxes in net income by income group shows only little variation between deciles; if measured as proportion of expenditure an inverted U-shape is found, i.e. households in the middle expenditure

[13] I.e. whether the assessment is based on income or expenditure (see also Kirchner et al., 2018).

deciles bear the largest burden. Taxes on heating fuels and electricity are found to be regressive in Finland, both on an income and on an expenditure basis.

Sterner (2012) assesses the distributional effects of energy taxes on transport fuels in eleven European countries. Only for two countries, Spain and Sweden, he finds some evidence of regressivity on an income basis. For most countries, however, the tax burden is shown to be approximately proportional.

Wier et al. (2005) study the distributional effects of carbon taxes on heating fuels and electricity in Denmark. Their study finds Danish CO_2 taxes to be regressive[14]. In absolute terms CO_2 tax payments increase with household payments, but their share in the household budget declines with rising income[15]. Comparing CO_2 taxes with other Danish levies, Wier et al. (2005) find them to be more regressive than the average Danish levy, including VAT taxes.

A review by Kosonen (2012) focussing on Denmark, Finland, Sweden and Norway also confirms that the distributive impacts of carbon taxes differ with respect to the application area, and tend to be regressive for heating and electricity, but not with respect to mobility.

6 Conclusions

The minimum tax rates established by the energy taxation directive (Directive 2003/96/EC) are not sufficient in order to establish the price signal required to meet the EU's climate mitigation targets. This has already been noted in the Presidency Conclusions of the European Council of March 2008 with respect to the 2020 energy and climate targets.

Against this background, the European Commission proposed a reform of Directive 2003/96/EC for the post-Kyoto period in 2011. On the one hand, the minimum excise duties should be adapted to reflect the energy content of the energy sources. On the other hand, differences in the CO_2 content of the fuels should be considered in the revised directive[16]. In addition, an adapted framework taxing renewable energy sources should be provided and interaction effects with the EU ETS should be accounted for. As to the CO_2 component, the European Commission proposed a uniform minimum tax rate of EUR 20 per tonne CO_2 for transport and heating fuels. Regarding the energy component, the Commission adhered to differentiated rates for different application areas: Energy tax

[14] This refers both to direct and indirect CO_2 payments, the latter denoting increases in prices of energy-intensive goods and services when CO_2 taxes are imposed on industry.

[15] IEEP (2013) notes that a study by Jacobsen et al. 2001 found that energy taxes (which also include the CO_2 tax) are regressive, however when total expenditure instead of disposable income is used as the basis of calculation, the regressivity of energy taxes nearly disappears.

[16] Energy tax rates should based on the net calorific value of the energy sources; the CO_2 component should be based on the fuel-specific reference emission factors applied under the EU ETS.

rates for transport fuels would be significantly higher than for heating fuels (EUR 9.6 per GJ as compared to EUR 0.15 per GJ) and reduced energy tax rates in the transport sector (e.g. for diesel) would be raised to the level of petrol tax rates over the period 2013 to 2018.

The Commission's proposal has not been adopted due to resistance from some Member States and the requirement of unanimity for EU taxation issues. Hence, Member States' energy tax rates still show pronounced differences and CO_2 emissions of the fuels are rarely taken into account when determining the tax rates.

Energy and carbon taxation can, though, make a significant contribution towards achieving emission reductions, particularly in the transport sector where greenhouse gas emissions continue to be on the rise in the EU. Evidence on the economic impacts of energy and carbon taxes furthermore shows that a double dividend, i.e. the achievement of a reduction of emissions and simultaneous positive macro-economic effects, can be achieved. With respect to the distributional impacts of carbon and energy taxes evidence is, however, mixed. While studies generally negate regressive effects of taxes on propellants, energy and carbon taxes on heating fuels tend to be found regressive.

Since an EU-wide approach towards energy and carbon taxation seems out of reach, Member States should consider carbon taxes at the national level in view of achieving the respective greenhouse gas reduction targets in sectors not covered by the EU ETS.

Acknowledgements

The research is part of the project 'CATs – Carbon Taxes in Austria: Implementation Issues and Impacts' that was funded by the Austrian 'Klima- und Energiefonds' and carried out within the Austrian Climate Research Programme ACRP. We highly appreciate the helpful feedback of Margit Schratzenstaller on an earlier draft of this working paper.

7 References

Andersen M.S., T. Barker, E. Christie, P. Ekins, J.F. Gerald, J. Jilkova, S. Junankar, M. Landesmann, H. Pollitt, R. Salmons, S. Scott and S. Speck (eds.) (2007), Competitiveness Effects of Environmental Tax Reforms (COMETR). Final report to the European Commission. National Environmental Research institute, University of Aarhus.

Andersen M.S. (2004), Vikings and virtues: a decade of CO_2 taxation, Climate Policy 4, 13–24.

Bjorner T.B. and H.H. Jensen (2002), Energy taxes, voluntary agreements and investment subsidies-A micro-panel analysis of the effect on Danish industrial companies' energy demand, Resource and Energy Economics 24(3), 229–249.

Böhringer C. and R Schwager (2002), 'Die ökologische Steuerreform in Deutschland – ein umweltpolitisches Feigenblatt', Discussion Paper 02-14 DIW.

Brännlund F., T. Lundgren and P.O. Marklund (2014), Carbon intensity in production and the effects of climate policy—Evidence from Swedish industry, Energy Policy 67, 844–857.

Council Directive 2009/29/EC of 23 April 2009 amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community, Brussels.

Council Directive 2003/96/EC of 27 October 2003 restructuring the Community framework for the taxation of energy products and electricity, Brussels.

Council Directive 92/82/EEC of 19 October 1992 on the approximation of the rates of excise duties on mineral oils, Brussels.

EC (2017), Excise Duty Tables January 2017.

EC (2017), Weekly Oil Bulletin.

Enevoldsen M.K., A.V. Ryelund and M.S. Andersen (2007), Decoupling of industrial energy consumption and CO_2-emissions in energy-intensive industries in Scandinavia, Energy Economics 29, 665–692.

Eurostat (2018), Environmental tax revenues. Extracted on 21 February 2018.

Flues F. and A. Thomas (2015), “The distributional effects of energy taxes”, OECD Taxation Working Papers, No. 23, OECD Publishing, Paris. http://dx.doi.org/10.1787/5js1qwkqqrbv-en.

IEEP (2013), Evaluation Of Environmental Tax Reforms: International Experiences Annexes To Final Report.

Infras and Ecologic (2007), Erfahrungen mit Energiesteuern in Europa – Lehren für die Schweiz.

Jacobsen H.K., K. Birr-Pedersen and M. Wier (2001), 'Fordelningsvirkninger af energi- og miljöafgifter', (Distributional effects of energy and environmental taxes), Risö National Laboratory, Roskilde.

Kirchner M., M. Sommer, C. Kettner, D. Kletzan-Slamanig, K. Köberl and K. Kratena (2018), CO_2 tax scenarios for Austria – Impacts on household income groups, CO_2 emissions, and the economy, WIFO Working Paper No. 558, http://www.wifo.ac.at/wwa/pubid/60975.

Kosonen K. (2012), Regressivity of environmental taxation: myth or reality?, in: Milne J. and M. Skou Andersen (eds.) Handbook of Research on Environmental Tax Reform, Cheltenham/Massachusetts, Edward Elgar, 161–174.

Skjærseth J.B. and J. Wettestad (2008), EU emissions trading: initiation, decision-making and implementation, Aldershot, Ashgate Publishing.

Sairinen R. (2012), Regulatory reform and development of environmental taxation: the case of carbon taxation an ecological tax reform in Finland, in: Milne J. and M.S. Andersen (eds.), Handbook of Research on Environmental Tax Reform, Cheltenham/Massachusetts, Edward Elgar, 422–438.

Speck S. (2008), 'The design of carbon and broad-based energy taxes in European countries', Vermont Journal of Environmental Law, 10 (1), 31-59.

Speck S., M.S. Andersen, H.O. Nielsen, A. Ryelund and C. Smith (2006), The use of economic instruments in nordic and baltic environmental policy 2001-2005, Nordic Council of Ministries, Copenhagen.

Sterner T. (2012), Distributional effects of taxing transport fuel, Energy Policy 41, 75–83.

UNFCCC (2017), National Inventory Reports 2017.

Weishaar S.E. (2018), Introducing carbon taxes at Member State level – Issues and barriers, WIFO Working Paper No. 557, http://www.wifo.ac.at/wwa/pubid/60974.

Wier M., K. Birr-Pedersen, H.K. Jacobsen and J. Klok (2005), Are CO_2 taxes regressive? Evidence from the Danish experience, Ecological Economics 52, 239–251.