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Road fuel taxes in Europe: Do they internalize road transport externalities?

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ABSTRACT

All countries in Europe have road fuel taxes and these account for roughly half of the net fuel price. We compare current road fuel taxes and corrective taxes, estimated on the basis of negative externalities from road transport for 22 European countries, taking into account the effect of fuel taxation on fuel efficiency. We focus on cars running on diesel or petrol and commercial vehicles running on diesel. If fuel taxes were intended to internalize all road transport externalities, then a number of countries could be considered to be on the right path already in what respects petrol taxation. Diesel, on the other hand, seems to be under-taxed in all 22 countries. Petrol tax increases would be in order in some countries and diesel tax increases would be in order in all 22 countries, at least as a bridge until fine-tuned policies, such as widespread peak congestion pricing or pay-as-you-drive insurance can be put in place.

1. Introduction

Road transport generates negative externalities. These include air pollution, congestion, accidents, noise and climate change, linked to Greenhouse Gas (GHG) emissions (Newbery, 1990; Parry et al., 2007; Small and Verhoef, 2007; Becker et al., 2012).[1] To correct externalities in road transport policy-makers tend to rely either on a command-and-control approach (CAC), or on taxes, or a combination of both.[2] A standard result is that taxes are more efficient than CAC from an economic theory point of view. However, CAC mechanisms are often preferred by policy-makers and consumers because they do not entail visible or direct financial costs and have a lower political cost. An example of this are the Corporate Average Fuel Economy (CAFE) standards used in the US.

Although fuel price elasticities are low,[3] there is some evidence that consumers respond more strongly to fuel tax changes than to changes in tax-inclusive prices (Li et al., 2014). In addition to this, fuel taxes are more efficient than fuel economy taxes and subsidies on vehicles (Sallee, 2010), and fuel economy standards (Li et al., 2014). Also, fuel taxes are already in place in many countries[4] and, being paid at the point of fuel purchase, they are easy, quick and inexpensive to collect. In Europe, fuel taxes represent on average roughly half of the net fuel price, as shown in Figs. 1–3. The graphs show 2008 values at 2010 prices, for consistency throughout the paper. Most parameters, estimates and traffic data correspond to the year 2008 or latest possible before 2008.

Fuel taxes are an attractive economic instrument to internalize transport negative externalities (Newbery, 2001; Small, 2010). Having said that, fuel taxes are very blunt instruments for externalities that vary with time and location of the trip and/or with vehicle type and characteristics (Newbery, 2001, p. 6) and this is a widely recognized fact. Parry and Small (2005, p. 1276), for example, state that ‘except for carbon dioxide, it would be better that a tax be placed on something other than fuel: local emissions, peak-period congestion, or miles driven, preferably with a rate that varies across people with different risks of causing accidents. Nonetheless, ideal externality taxes have not been widely implemented: they raise objections on equity grounds, they require administrative sophistication, and there is often stiff political opposition to introducing new taxes. The fuel tax, by contrast, is administratively simple and well established in principle, even at very

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[1] Santos et al. (2010) provide a thorough review of road transport externalities and economic instruments to internalize them.

[2] Another option, at least in theory, would be the implementation of cap-and-trade systems. Although aviation was included in the European Union Emissions Trading Scheme (EU ETS) in January 2012, no cap-and-trade system has ever been implemented in road transport. However, over the last few years the academic literature has been actively assessing the idea of tradable permits to regulate road transport externalities (Verhoef et al., 1997), including air pollution (Raux, 2004) and CO_2 emissions (Albrecht, 2001; Raux and Marlot, 2005; Watters et al., 2006; Wadud et al., 2008; Abrell, 2010). Tradable permits in road transport are, for the time being, a theoretical idea, and fall outside the scope of this study.

[3] Both short- and long-run fuel price elasticities are under 1. For reviews see for example Graham and Glaister (2002) or Goodwin et al. (2004).

[4] Middle East and North African countries do not tax, but instead subsidize fossil fuels (Parry et al., 2014, pp. 26–27).

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Acronym	Country		
AT	Austria	HU	Hungary
BE	Belgium	IE	Ireland
CH	Switzerland	IT	Italy
CZ	Czech Republic	LU	Luxembourg
DE	Germany	NL	Netherlands
DK	Denmark	PL	Poland
EE	Estonia	PT	Portugal
ES	Spain	SE	Sweden
FI	Finland	SI	Slovenia
FR	France	SK	Slovakia
GR	Greece	UK	United Kingdom

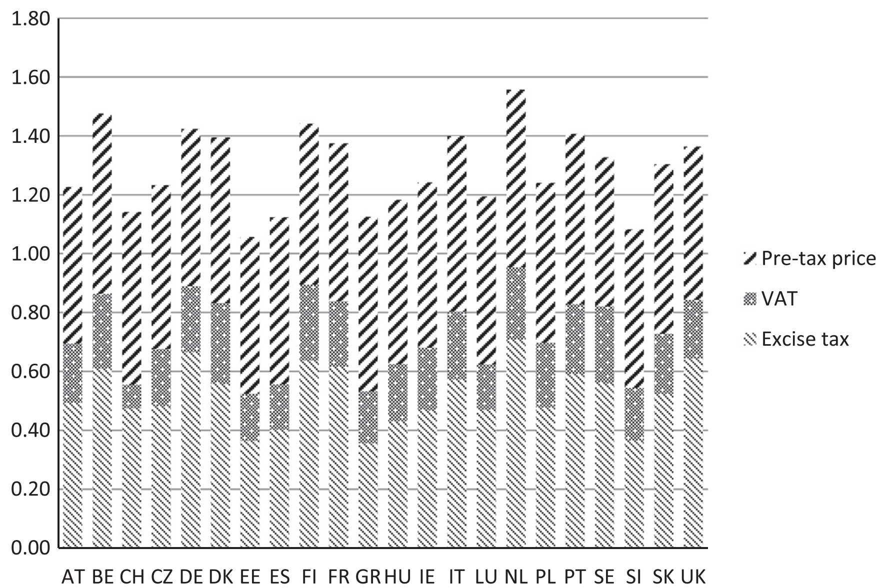

Fig. 1. Petrol prices in Europe, in €/L (2008 values and 2010 prices).
Source: International Energy Agency (2013)

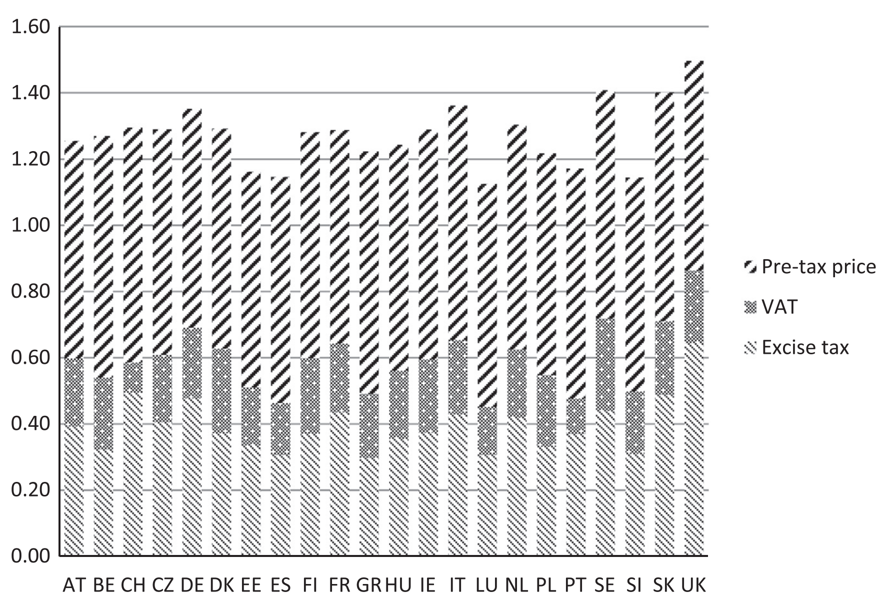

Fig. 2. Diesel prices in Europe, for cars, in €/L (2008 values and 2010 prices).
Source: International Energy Agency (2013)

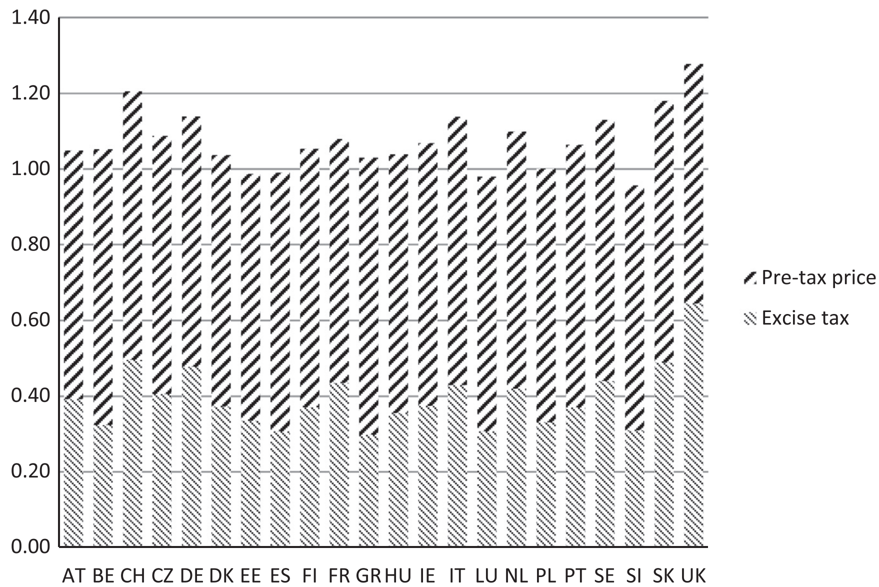

Fig. 3. Diesel prices in Europe, for Heavy Duty Vehicles (HDVs), in €/L (2008 values and 2010 prices).
Source: International Energy Agency (2013)

high rates in many nations. Therefore it is entirely appropriate to consider how externalities that are not directly priced should be taken into account in an assessment of fuel taxes.' Distance-related taxation instead of, or as a complement to, fuel taxes, would be a better instrument (Parry and Small, 2005; Parry, 2008; Parry, 2009). The feasibility of a distance-related tax is, however, uncertain, mainly due to lack of public acceptability (Schade and Schlag, 2003, p. 43). In any case, fuel taxes (or a carbon tax embedded in the fuel tax) stand as the perfect instrument to internalize the external costs from CO_2 emissions (Newbery, 1992, 2001; Parry and Small, 2005; Parry, 2007; Sterner, 2007) because CO_2 emissions are closely related to fuel consumption. Indeed, many governments defend fuel taxes on environmental grounds (Newbery, 2005a, p. 24). The undeniable fact that CO_2 emissions are causing climate change has emerged as a politically acceptable reason for having and even increasing fuel taxes.

Although Parry and Small (2005, p. 1277) recognize that global warming is 'the only component for which the fuel tax is (approximately) the right instrument', they still estimate the fuel taxes that would internalize, even if imperfectly, pollution, congestion and accidents in the US and in the UK. This is consistent with Newbery (1992), who argues that the carbon tax should be added to the tax on other motor fuel related externalities. On the same lines, Parry and Strand (2012) and Parry and Timilsina (2015) estimate corrective fuel taxes taking into account most transport externalities for Chile and Greater Cairo Metropolitan area, respectively. Other papers in the same spirit include Newbery (1990), Acutt and Dodgson (1997), Newbery (2005b), Parry and Small (2005), Ley and Boccardo (2010), Parry et al. (2012) and Parry et al. (2014).

If fuel taxes on road transport were designed as an instrument to internalize externalities, with the caveats described above, then fuels should not be taxed the same amount in every (EU) country, because the external costs generated by road transport differ from one country to another. In 2003, the Energy Taxation Directive (Official Journal of the European Union, 2003, Directive 2003/96/EC, 27 October) fixed a common minimum excise on fuels. However, EU member states are still free to set higher taxes if they wish to.

Fuel taxes in Europe are not designed as efficient economic instruments. Rietveld and van Woudenberg (2005) regress fuel taxes on externality levels (proxied by car density in each country) and find no significant relationship between these two variables. They also find that as the share of government expenditure in GDP increases, the fuel tax tends to increase and conclude that fuel taxes tend to be designed as an instrument to raise fiscal revenues and to finance government expenditure, rather than to correct externalities. Although fuel taxes may have a pure tax element to raise revenues (after all, governments need revenues to fund schools, hospitals, etc.) fuel taxes should be transparent. Thus, the pure and corrective tax components should be clearly differentiated and the latter should be 'based on a careful assessment of the relevant costs to be charged out' (Newbery and Santos, 1999, p. 115). The aim of the present study is to estimate the fuel tax that would internalize all road transport externalities, even if imperfectly, on the assumption that no other instruments were in place. We do this for 22 European countries.[5]

We fully acknowledge that a fuel tax would only be adequate to internalize the climate change externality, and to some extent, air pollution, whereas it would not be ideal to internalize congestion and accidents, which would be better internalized with instruments that specifically targeted them, such as congestion charges and pay-as-you-drive insurance, respectively. However, until these types of road user charges become widely implemented, 'reflecting all of these costs in motor fuel taxes is appropriate' (Parry et al., 2014, pp. 3–4), at least as an intermediate step. It would be socially costly to wait until a first-best fine-tuned charging system can be applied to different road transport externalities.

Bearing all this in mind, we use inverted commas throughout the paper and call this tax, a 'corrective' tax. By using inverted commas we emphasize the idea that although the tax attempts to correct for all road transport externalities, it is a blunt instrument.

Ours is a partial equilibrium analysis, as we do not model the whole fiscal system, nor do we take into account interactions between fuel taxes and other taxes. We also restrict our analysis to diesel and petrol, since these are the two main fuels used by road transport in Europe. Other fuels represent a very small proportion of total fuel consumption, as can be seen in Fig. 4.

The paper proceeds as follows. Section 2 presents estimates of the Marginal External Costs from road transport in our 22 European countries. Section 3 presents estimates of fuel taxes that would account for road transport externalities, even though imperfectly, as the only externality that can be efficiently internalized with a fuel tax is the

[5] We only excluded countries for which there was not enough available data.

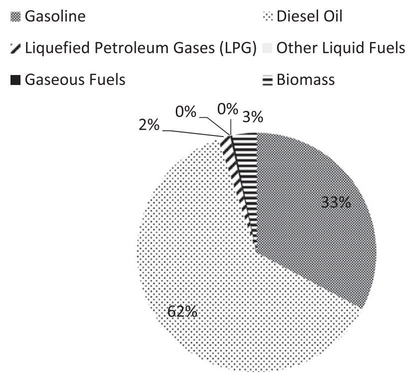

Fig. 4. Share of each fuel in road transport energy consumption for EU-27 in 2008.
Source: Data provided on request by the European Environment Agency

climate change externality. Section 4 concludes and presents lines for future research.

2. Marginal external costs from road transport in Europe

In this section we present estimates of the marginal external costs (MEC) from road transport for 22 European countries. We consider five externalities: climate change due to GHG emissions (carbon component), local pollution, accidents, congestion, and noise.

We do not estimate the external costs of transport from scratch but use the estimates produced and refined over the last 15 years by different EU-funded research projects and combine them with traffic data from the TREMOVE (**TR**ansport and **E**missions **Mo**del) database.[6] We then use these results and the model developed by Parry and Small (2005) to estimate the 'corrective' fuel tax that would account for road transport externalities in each of the 22 countries.

2.1. Carbon component

Fuel combustion generates carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), which are GHG and contribute to global warming. To estimate the impact of different types of emissions on global warming it is common practice to convert them into CO_2 equivalent (CO_2e), using their global warming potential. Formally, the link between CO_2e emissions and quantity of fuel burnt is the following:

$$Q^C = \sum_{i=CO_2,CH_4,N_2O} \gamma_i \rho_i F \tag{1}$$

where Q^C is the quantity of CO_2e emitted, γ_i is the fuel emission factor, ρ_i is the global warming potential, and F is the quantity of fuel consumed.

In order to convert the GHGs to CO_2e we used the global warming potential[7] factors over 100 years from the United Nations Framework Convention on Climate Change (UNCC),[8] which are 1 for CO_2, 21 for CH_4, and 310 for N_2O.

Emission factors vary with fuel type and across countries. This is because different countries use different types of petrol and diesel. For each country, we used the 2008 emission factors provided on request by the European Environment Agency (EEA), after converting them from kg/TJ units to kg CO_2e/L units using the country specific 2008 conversion factors from the International Energy Agency (IEA, 2008, pp. 51–52) for petrol and diesel, respectively. Table 1 presents the emission factors we used.

Table 1
Emission factors for petrol and diesel.
Source: Converted from EEA figures, provided on request. The EEA provided us only with data for EU member states. For Switzerland we used the EU-27 averages: 2.528 kg CO_2e/L for petrol and 2.767 kg CO_2e/L for diesel. On average, 98% of these emissions are from CO_2 and the remaining 2%, from CH_4 and N_2O.

Country	Emission factor (kg CO_2e/L)	
	Petrol	Diesel
AT	2.514	2.703
BE	2.293	2.755
CH	2.528	2.767
CZ	2.618	2.697
DE	2.420	2.692
DK	2.576	2.694
EE	2.590	2.752
ES	2.516	2.732
FI	2.587	2.783
FR	2.506	2.757
GR	2.452	2.772
HU	2.403	2.650
IE	2.471	2.751
IT	2.394	2.656
LU	2.455	2.765
NL	2.449	2.730
PL	2.333	2.679
PT	2.500	2.706
SE	2.537	2.697
SI	2.567	2.757
SK	2.465	2.735
UK	2.335	2.742
EU-27	2.528	2.767

As it can be seen from Table 1, the emission factor for diesel is always higher than the emission factor for petrol when it is expressed in kg of CO_2e emitted per litre of fuel. However, the emission factor for diesel is always *lower* than the emission factor for petrol when it is expressed in kg of CO_2e emitted per vehicle-kilometre because diesel has a higher fuel efficiency than petrol.

To estimate the carbon component[9] of the marginal external cost, we multiplied the quantity of CO_2e emitted by the Social Cost of Carbon (SCC). There is substantial controversy around the SCC and there have been a number of studies attempting to estimate it (Nordhaus, 1991, 1994; Cline, 1992; Fankhauser, 1994; Tol, 1999; Tol and Downing, 2000) as well as a number of reviews (Clarkson and Deyes, 2002; Tol, 2005, 2008), including a couple of reviews by the UK government (UK Department of Energy and Climate Change, DECC, 2009)[10] and by the US government (US Interagency Working Group on Social Cost of Carbon, IAWG, 2013). The values differ substantially and in a study like this one it makes sense to err on the side of caution and use the central estimate suggested by US IAWG (2013), which is only US $35 per tonne of CO_2 for 2010 at 2010 prices, or €26.4, in contrast with £53.8, also for 2010 at 2010 prices, or €62.8, the central value suggested by the UK government in the latest update of traded and non-traded CO_2e prices (UK DECC, 2015a, Table 3).[11]

[6] The data from TREMOVE, an economic, transport and emissions policy assessment model developed for the European Commission by the Catholic University of Leuven and Transport &$2 Mobility Leuven, was taken from http://www.tremove.org/documentation/. We used the base-case pivots, version 2.7b.

[7] Global warming potential is a relative measure of how much heat a greenhouse gas traps in the atmosphere.

[8] http://unfccc.int/ghg_data/items/3825.php

[9] Carbon content is expressed in CO_2e. This does not mean that we refer only to CO_2, but that we converted every GHG into its equivalent CO_2 quantity.

[10] The review resulted in DECC adopting an approach that moved away from a valuation based on the damages associated with climate change (commonly known as the SCC). Instead, the values are now based on the UK government reduction targets and the cost of mitigating emissions.

[11] Because in the EU there are separate emissions reduction targets for the traded sector (where emissions are covered by the EU Emission Trading Scheme, EU ETS) and for the non-traded sector (where emissions are not covered by the EU ETS), the UK government treats emissions in the two sectors as different commodities and values them differently: CO_2e emissions which occur in the traded sector are valued at the Traded Price of Carbon, whereas CO_2e emissions in the non-traded sector are valued at the Non-Traded Price of Carbon (UK DECC, 2015b, p. 11).

Table 2
Marginal external cost of carbon emissions from petrol and diesel (2008 values and 2010 prices).
Source: Values from Table 1 multiplied by the SCC from US IAWG (2013).

Country	MEC of carbon (ct€/L)	
	Petrol	Diesel
BE	6.06	7.28
CH	6.68	7.31
CZ	6.92	7.13
DE	6.39	7.11
DK	6.81	7.12
EE	6.84	7.27
ES	6.65	7.22
FI	6.84	7.35
FR	6.62	7.29
GR	6.48	7.32
HU	6.35	7.00
IE	6.53	7.27
IT	6.33	7.02
LU	6.49	7.31
NL	6.47	7.21
PL	6.16	7.08
PT	6.61	7.15
SE	6.70	7.13
SI	6.78	7.29
SK	6.51	7.23
UK	6.17	7.25
EU-27	6.68	7.31

The marginal external cost of carbon from road transport can therefore be estimated as

$$E^{P_F} = SCC.\ Q^C \tag{2}$$

where E^{P_F} is the external cost of carbon, SCC is the Social Cost of Carbon, and Q^C is the quantity of carbon emitted.

Table 2 shows our estimates of the marginal external cost of carbon for our 22 countries, using the US IAWG (2013) SCC. The figures presented in Table 2 show that if fuels were to be taxed only according to their carbon emissions, fuel taxation would be significantly lower than it currently is.[12]

2.2. Other components of MEC

The other components of the MEC of road transport are air pollution, congestion, noise and accidents.

Fuel combustion does not only emit GHG but is also an important source of air pollution (Parry et al., 2007), as it emits particulate matter (PM_{10}, $PM_{2.5}$), nitrogen oxides (NO_X), sulphur dioxide (SO_2), and volatile organic compounds (VOC). These substances have a negative impact on human health (Banister, 1998; Kampa and Castanas, 2008). Air pollution also causes building degradation, agricultural damage and has negative effects on natural ecosystems. These impacts occur mostly at a local scale. For this reason the marginal external cost of air pollution varies with location. It also depends, although to a lesser extent, on time of the day, weather conditions and congestion levels prevailing at the time the vehicle is driven. Thus, even though fuel taxes may be good instruments to internalize the global warming externality, they may be less effective at targeting local air pollution (Crawford and Smith, 1995, p. 34).

Traffic congestion is essentially characterized by slow speeds, and takes place when the demand for road space is greater than road capacity. Congestion costs 'arise because additional vehicles reduce the speed of other vehicles, and hence increase their journey time' (Newbery, 1990, p. 27). Longer and unreliable travel times are costly and inevitably also cause an inefficient distribution and delivery of goods and services. Drivers do not take into account the time cost they impose on other road users, they only take into account their own travel time costs, including those due to congestion. Obviously, marginal external congestion costs are closely linked to time and location, and in that sense, fuel taxes can only act as blunt instruments to internalize them (Newbery, 2001, p. 6), as they do not discriminate between routes or between peak and off-peak times. Congestion charging would be a much better suited economic instrument to internalize this externality, especially if congestion charges varied with congestion levels (Newbery, 1990; Parry et al., 2014, p. 101) and vehicle size.

Noise constitutes another road transport externality (UK Department for Transport, DfT, 2015) as it harms human health and interferes with people's daily activities. According to the World Health Organization (WHO), noise from road transport affects the health of almost one third of people in Europe (WHO website, 2016). Noise can interfere with 'people's daily activities at school, at work, at home and during leisure time. It can disturb sleep, cause cardiovascular and psychophysiological effects, reduce performance and provoke annoyance responses and changes in social behaviour' (WHO website, 2016). Like in the case of air pollution and congestion, noise varies with time and location of the journey.

Finally, accident externalities arise 'whenever extra vehicles on the road increase the probability that other road-users will be involved in an accident' (Newbery, 1990, p. 24). External accident costs are the accident costs 'not covered by risk oriented insurance premiums' (Maibach et al., 2008, p. 36) and include items (or part of items) such as material damage, medical costs, lost economic output, and the pain, grief and suffering imposed on the victims, and their friends and families (Maibach et al., 2008, p. 36; UK DfT, 2014, p. 3). Accident externalities do not depend directly on fuel consumption and fuel taxes are not the best economic instrument to internalize them.

The most natural unit to express air pollution, congestion, noise and accident external costs is Euro cents per vehicle-kilometre (€ct/vkm).[13] Table 3 presents marginal external costs by country for petrol cars, diesel cars and Heavy Duty Vehicles (HDVs), which we define, following Maibach et al. (2008), as lorries whose gross weight is above 3.5 tonnes. In addition, we assumed that half of the cars run on petrol and half run on diesel.

Following the recommendation in Maibach et al. (2008), this is the way we computed congestion costs for each country: EU average congestion cost per car-km on urban roads at peak times multiplied by the share of car-km on urban roads at peak times in the country in question plus EU average congestion cost per car-km on interurban roads at peak times multiplied by the share of car-km on interurban roads at peak times in the country in question. And for HDVs we did exactly the same but using the EU average congestion cost per HDV-km and the share of HDV-km instead. The shares of traffic were computed using data on traffic on different types of road at peak times from the TREMOVE database,[14] assuming dense traffic on urban roads and thin traffic on non-urban roads, in line with the recommendation from Maibach et al. (2008). The EU-average central values of marginal congestion costs at peak times were taken straight from Table 7 in Maibach et al. (2008, p. 34).

The average of the resulting congestion cost estimates for the

[12] The same conclusion would apply even if we were to use the UK DECC (2015a) non-traded value of CO_2e, which is 2.4 times higher than the US IAWG (2013) value.

[13] We are not arguing that noise, congestion and accidents are proportional to or well-represented by vehicle-kilometres.

[14] The shares in TREMOVE correspond to the year 2006 and not 2008, like the rest of the estimates and data. However, shares can be expected to be stable, especially over a period of only two years.

Table 3
Estimates of the air pollution, congestion, accidents and noise components of the marginal external costs of road transport, by country, in €ct/vkm (2008 values and 2010 prices).

Country	Pollution			Congestion			Accidents			Noise			Total		
	Cars		HDVs	Cars		HDVs	Cars		HDVs	Cars		HDVs	Cars		HDVs
	Petrol	Diesel	Diesel	Petro	Diesel	Diesel	Petro	Diesel	Diesel	Petro	Diesel	Diesel	Petro	Diesel	Diesel
AT	0.59	1.21	6.92	6.27	6.27	15.55	4.24	4.24	1.20	0.33	0.33	17.06	11.43	12.04	40.72
BE	0.60	1.22	6.99	5.60	5.60	15.32	3.63	3.63	5.75	0.33	0.33	20.62	10.16	10.78	48.68
CH	0.62	1.28	7.50	6.58	6.58	19.96	1.46	1.46	7.26	0.34	0.34	34.75	8.99	9.66	69.47
CZ	0.64	1.35	7.13	6.83	6.83	15.77	7.50	7.50	4.26	0.39	0.39	23.11	15.36	16.07	50.27
DE	0.61	1.24	7.11	6.18	6.18	17.08	2.71	2.71	4.04	0.38	0.38	28.38	9.87	10.51	56.61
DK	0.64	1.38	7.38	6.01	6.01	16.69	3.11	3.11	1.34	0.34	0.34	23.92	10.10	10.84	49.34
EE	0.74	1.65	6.87	8.85	8.85	14.07	5.84	5.84	3.38	0.49	0.49	13.38	15.93	16.84	37.70
ES	0.64	1.35	7.34	6.78	6.78	19.53	2.69	2.69	4.40	0.39	0.39	31.57	10.50	11.21	62.84
FI	0.67	1.46	7.85	6.54	6.54	17.91	4.01	4.01	3.13	0.38	0.38	32.19	11.59	12.39	61.08
FR	0.62	1.27	7.29	6.89	6.89	19.46	1.82	1.82	4.75	0.39	0.39	34.46	9.71	10.36	65.96
GR	0.68	1.47	7.30	7.44	7.44	16.52	12.95	12.95	8.99	0.43	0.43	27.61	21.50	22.30	60.42
HU	0.55	1.10	NA	2.69	2.69	NA	5.67	5.67	NA	0.22	0.22	NA	9.13	9.68	NA
IE	0.66	1.44	8.16	6.36	6.36	18.15	5.08	5.08	5.95	0.34	0.34	32.59	12.44	13.22	64.85
IT	0.58	1.18	6.93	6.02	6.02	16.78	3.41	1.82	2.34	0.30	0.30	18.02	10.32	9.33	44.07
LU	0.71	1.49	8.02	8.02	8.02	25.54	8.15	8.15	18.00	0.60	0.60	72.70	17.47	18.25	124.26
NL	0.63	1.32	7.25	6.67	6.67	16.48	1.55	1.55	1.95	0.38	0.38	26.88	9.23	9.92	52.56
PL	0.63	1.33	6.96	6.71	6.71	15.77	4.14	4.14	3.09	0.33	0.33	15.30	11.80	12.50	41.13
PT	0.65	1.41	7.25	6.29	6.29	15.08	2.60	2.60	2.99	0.34	0.34	16.60	9.88	10.64	41.91
SE	0.64	1.35	7.46	6.95	6.95	18.81	3.06	3.06	3.32	0.41	0.41	37.63	11.06	11.77	67.22
SI	0.70	1.50	7.02	7.71	7.71	15.84	6.96	6.96	5.18	0.42	0.42	23.42	15.80	16.60	51.45
SK	0.60	1.23	NA	6.67	6.67	NA	4.59	4.59	NA	0.32	0.32	NA	12.17	12.81	NA
UK	0.68	1.44	7.70	8.09	8.09	21.21	2.23	2.23	3.56	0.50	0.50	54.21	11.50	12.25	86.69
EU-27	0.62	1.27	7.29	6.89	6.89	19.46	2.64	2.64	3.53	0.39	0.39	34.46	10.53	11.18	64.75

Note: NA: not available due to lack of traffic repartition data for HDVs from the TREMOVE database

European countries in question is only slightly higher than the average congestion cost estimated for those same countries by Parry et al. (2014), as it can be seen from their associated spreadsheets.[15] The ratio of the two averages is 0.98.

The values of time on which the congestion cost estimates in Maibach et al. (2008) rest do not take income into account but are instead based on a meta-analysis conducted by Bickel et al. (2006), which uses data collected from Willingness-To-Pay surveys in different countries.

Similarly, for air pollution costs, we used the air pollution costs per car-km and HDV-km, as reported in Table 34 in Van Essen et al. (2011), and combined these with traffic data from each country and type of area from TREMOVE. The air pollution costs in Van Essen et al. (2011) include the costs for $PM_{2.5}$, PM_{10}, non-methane volatile organic compound (NMVOC), sulphur dioxide (SO_2) and nitrogen oxides (NO_x).

Van Essen et al. (2011) update the values for NMVOC, SO_2 and NO_x from Preiss et al. (2008) and the values for $PM_{2.5}$ and PM_{10} from Maibach et al. (2008), who in turn update theirs from Bickel et al. (2006), who base their values on the ExternE set of projects (European Commission, 2005) and ExternE's EcoSense System, which is an integrated software tool where emission sources are distinguished by administrative region, economic activity and emission height (Bickel and Droste-Franke, 2006). As it can be seen from Table 3, the local air pollution component of the marginal external cost is higher for diesel than for petrol, even when expressed per vehicle-kilometre. This is because diesel emits more particulate matter.[16]

The air pollution cost estimates in Table 3 in the present study, which are based on Van Essen et al. (2011), are higher than the air pollution cost estimates in Parry et al. (2014) and their associated spreadsheets. The differences in the estimates between the European approach (i.e., the set of EU-funded projects on which air pollution cost estimates in Van Essen et al., 2011, are based) and Parry et al. (2014) stem from three points: (a) in Europe the costs of air pollution not only include (acute and chronic) mortality, but also morbidity, building and material damages and crop losses; (b) PM_{10} and NMVOC are not included in Parry et al. (2014); and (c) NO_x costs in Parry et al. (2014) are very low, relative to those estimated by different European projects.

Given the relatively small weight that air pollution has on total external costs when these are added up, these differences do not have much of an impact on the results and conclusions. In the extreme case that air pollution costs were assumed to be zero, the external costs of petrol used by cars, diesel used by cars, and diesel used by HDVs would be on average 95%, 89% and 86% of those computed in the present study, respectively. Of course, air pollution costs would never be equal to zero.

For accidents, the values from Table 33 in Van Essen et al. (2011, p. 102) were weighted by the share of traffic on each type of road for each country from TREMOVE. This yielded accident cost estimates which differ, on average, by a factor of 3.71 from those in Parry et al. (2014), even though the underlying average value of a statistical life is over 70% higher in Parry et al. (2014) than in Van Essen et al. (2011) for the countries in question. There are two reasons behind this difference:

First, our estimates, based on Van Essen et al. (2011), who in turn base theirs on Nash (2003) and its supporting intermediate document, Sommer et al. (2002), assume that all accident risks are external, and none is internalized (Van Essen et al., 2011, p. 103). For example, for Switzerland, for Sommer et al.'s base year 1998, external accident costs are 2.4 times higher if it is assumed that the accident risk of the responsible victim but not the one of the non-responsible victim is internalized relative to the case when it is assumed that the accident risk is fully internalized by the users of the transport system and is therefore not part of the external accident costs. In reality different countries will have different ratios of external to internal costs, and assuming either extreme will over and under estimate costs.

The second reason is that in addition to fatalities and non-fatal injuries, medical costs and property damage, Van Essen et al. (2011, p.

[15] Their spreadsheets are available on www.imf.org/environment.

[16] Furthermore, the local air pollution component of diesel may have been under-estimated given that diesel was classified as 'carcinogenic' by the WHO in June 2012 (International Agency for Research on Cancer, 2012). This decision had not yet been made when Van Essen et al. (2011) wrote their report.

Table 4
Fuel efficiency for cars and HDVs, in vkm/L (2008 values).
Source: ENERDATA (2012), Odyssee database.[a]

Country	Cars		HDVs
	Petrol	Diesel	
AT	12.65	15.15	3.60
BE	**13.23**	**15.63**	**3.25**
CH	**13.23**	**15.63**	**3.25**
CZ	**13.23**	**15.63**	**3.25**
DE	12.35	14.71	**3.25**
DK	13.04	12.87	3.01
EE	**13.23**	**15.63**	**3.25**
ES	12.48	14.96	3.23
FI	**13.23**	**15.63**	**3.25**
FR	12.90	15.15	2.84
GR	13.84	16.33	3.55
HU	11.90	16.13	**3.25**
IE	11.82	13.18	**3.25**
IT	15.27	17.70	**3.25**
LU	**13.23**	**15.63**	**3.25**
NL	12.31	14.83	3.05
PL	12.97	15.34	**3.25**
PT	12.82	13.97	3.27
SE	12.04	13.93	2.31
SI	12.60	14.89	4.19
SK	16.11	**15.63**	**3.25**
UK	14.11	16.98	3.40
EU-27	13.23	15.63	**3.25**

Note: The bold numbers for cars correspond to countries for which there was no data so the EU-27 average value was used instead. The bold numbers for HDVs correspond to countries for which there was no data. Odyssee did not have an EU average either so we computed the average of the values that were available and used this as an approximation for those countries where data was missing.

[a] Indicators "Average specific consumption of petrol cars", "Average specific consumption of diesel cars", and "Average specific consumption of trucks", available after free trial registration on http://www.odyssee-indicators.org/

32) also include, in line with Nash (2003) and its supporting papers, 'production losses caused by accidents when casualties are killed or not able to work in the direct aftermath of accidents', or at all. Parry et al. (2014) do not include this item, as they probably view it as an alternative approach to the value of a statistical life approach, as suggested by Freeman (2003).

External accident costs in the present study may have been overestimated, as in line with the tradition in EU studies, the estimates rest on the assumption that all accident costs are external. If accident costs were say, 50% lower, the final marginal costs, including all externalities, would be on average, 85% and 96% of those estimated here, for cars and HDVs, respectively.

For noise, the values from Table 37 in Van Essen et al. (2011) vary according to dense versus thin traffic, day or night time, and urban, suburban or rural road. Again, following the recommendation in Maibach et al. (2008), we assumed dense traffic on urban roads and thin traffic on non-urban roads. We then used traffic shares from TREMOVE to compute the marginal cost for the day and the marginal cost for the night. Finally, we assumed that 15% of HDVs and 10% of cars travel during night time, in line with French traffic data (Service d'Études Techniques des Routes et Autoroutes, 2007, p. 2).

In order to express all costs in monetary units per litre of fuel we multiply the values in Table 3 by fuel efficiency. Fuel efficiency is defined as the distance that can be driven with one litre of fuel, as follows:

$$f = \frac{M}{F} \quad (3)$$

where (f) is fuel efficiency, M is distance travelled, and F is fuel consumption. Table 4 presents fuel efficiency by country for cars and HDVs.

The full marginal external cost can thus be expressed as

$$MEC = E^{P_F} + f(E^{P_M} + E^C + E^A + E^B) \quad (4)$$

where MEC is the marginal external cost, expressed in €ct/L, E^{P_F} is the carbon component, expressed in €ct/L, f is fuel efficiency, expressed in vkm/L, E^{P_M} is the air pollution component of the marginal external

Table 5
Estimates of marginal external costs, by country, in €ct/L, at initial fuel efficiency (2008 values and 2010 prices).
Source: Tables 2–5.

Country	Carbon			Pollution			Congestion			Accidents			Noise			Total		
	Cars		HDVs	Cars		HDVs	Cars		HDVs	Cars		HDVs	Cars		HDVs	Cars		HDVs
	Petrol	Diesel	Diesel	Petrol	Diesel	Diesel	Petrol	Diesel	Diesel	Petrol	Diesel	Diesel	Petrol	Diesel	Diesel	Petrol	Diesel	Diesel
AT	6.64	7.14	7.14	7.50	18.30	24.91	79.32	94.96	56.00	53.63	64.19	4.32	4.16	4.98	61.43	151.25	189.58	153.80
BE	6.06	7.28	7.28	7.88	19.05	22.72	74.08	87.56	49.78	48.00	56.74	18.69	4.38	5.17	67.02	140.39	175.80	165.49
CH	6.68	7.31	7.31	8.14	20.09	24.38	86.97	102.80	64.86	19.36	22.88	23.60	4.46	5.27	112.93	125.61	158.36	233.08
CZ	6.92	7.13	7.13	8.49	21.16	23.18	90.37	106.82	51.24	99.16	117.21	13.85	5.17	6.11	75.11	210.11	258.43	170.51
DE	6.39	7.11	7.11	7.50	18.23	23.12	76.27	90.85	55.51	33.50	39.91	13.12	4.64	5.52	92.23	128.30	161.63	191.09
DK	6.81	7.12	7.12	8.38	17.78	22.21	78.35	77.35	50.27	40.54	40.02	4.04	4.38	4.32	72.03	138.46	146.60	155.67
EE	6.84	7.27	7.27	9.79	25.83	22.32	117.12	138.44	45.72	77.22	91.27	10.99	6.52	7.71	43.50	217.50	270.53	129.80
ES	6.65	7.22	7.22	7.97	20.12	23.87	84.61	101.44	63.47	33.60	40.29	14.30	4.80	5.76	102.59	137.63	174.83	211.44
FI	6.84	7.35	7.35	8.88	22.89	25.52	86.46	102.19	58.20	53.04	62.70	10.16	4.97	5.88	104.61	160.19	201.01	205.85
FR	6.62	7.29	7.29	7.96	19.19	23.70	88.94	104.39	63.24	23.42	27.49	15.43	5.01	5.88	112.00	131.95	164.24	221.65
GR	6.48	7.32	7.32	9.43	24.02	23.73	102.97	121.47	53.69	179.33	211.54	29.21	6.00	7.08	89.73	304.20	371.44	203.68
HU	6.35	7.00	NA	6.51	17.72	NA	32.07	43.45	NA	67.48	91.42	NA	2.58	3.50	NA	114.99	163.09	NA
IE	6.53	7.27	7.27	7.82	19.03	26.52	75.15	83.74	58.99	60.07	66.94	19.33	4.00	4.46	105.92	153.57	181.44	218.04
IT	6.33	7.02	7.02	8.88	20.89	22.54	91.94	106.58	54.52	52.08	32.28	7.61	4.65	5.39	58.56	163.87	172.17	150.25
LU	6.49	7.31	7.31	9.36	23.26	26.06	106.02	125.32	83.01	107.76	127.37	58.49	8.00	9.46	236.28	237.62	292.71	411.15
NL	6.47	7.21	7.21	7.76	19.59	23.57	82.09	98.92	53.56	19.09	23.00	6.34	4.63	5.58	87.35	120.05	154.31	178.03
PL	6.16	7.08	7.08	8.12	20.34	22.62	86.99	102.87	51.26	53.71	63.51	10.05	4.22	5.00	49.73	159.21	198.80	140.74
PT	6.61	7.15	7.15	8.36	19.69	23.57	80.59	87.79	49.00	33.33	36.31	9.71	4.40	4.79	53.94	133.27	155.73	143.37
SE	6.70	7.13	7.13	7.74	18.80	24.24	83.69	96.85	61.15	36.82	42.61	10.77	4.91	5.69	122.29	139.87	171.08	225.58
SI	6.78	7.29	7.29	8.81	22.34	22.80	97.12	114.76	51.48	87.73	103.66	16.82	5.35	6.32	76.12	205.79	254.36	174.51
SK	6.51	7.23	NA	9.63	19.28	NA	107.43	104.28	NA	73.90	71.74	NA	5.08	4.93	NA	202.56	207.47	NA
UK	6.17	7.25	7.25	9.59	24.43	25.03	114.07	137.32	68.92	31.48	37.90	11.58	7.03	8.47	176.19	168.35	215.36	288.97
EU-27	6.68	7.31	7.31	8.16	19.81	23.70	91.16	107.75	63.24	34.87	41.22	11.48	5.14	6.07	112.00	146.01	182.16	217.73

Note: NA: not available due to lack of traffic repartition data for HDVs from the TREMOVE database.

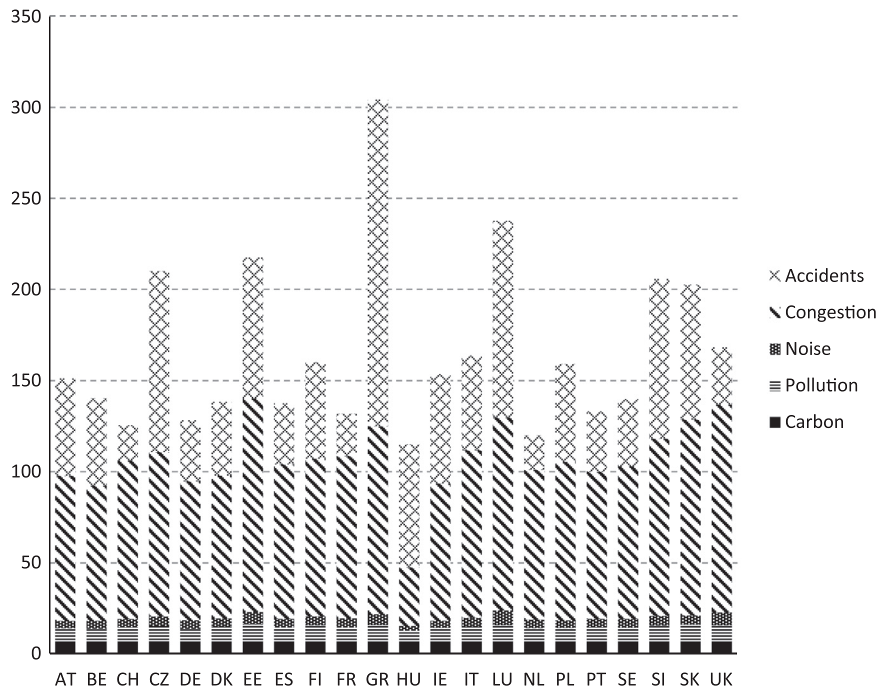

Fig. 5. Decomposition of the marginal external cost of petrol cars, in €ct/L (2008 values and 2010 prices).

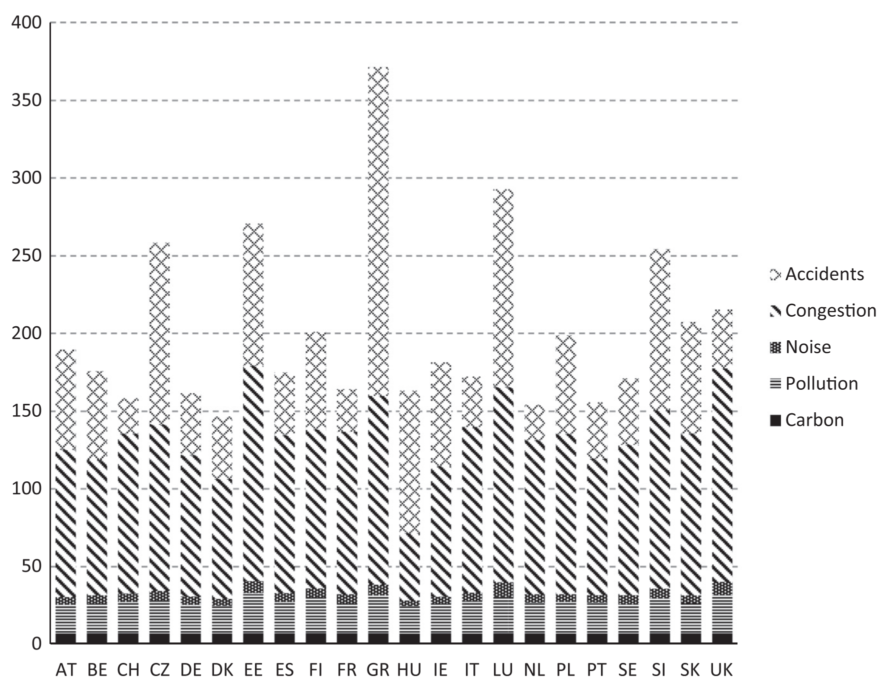

Fig. 6. Decomposition of the marginal external cost of diesel cars, in €ct/L (2008 values and 2010 prices).

cost, E^C is the congestion component, E^A is the accidents component, and E^B is the noise component, all expressed in €ct/vkm.

Table 5 presents all the components of the MEC as well as the total MEC per country and vehicle type. Figs. 5–7 illustrate the share of each component in MEC for petrol cars, diesel cars and HDVs.

Although many countries justify their high fuel duties on environmental grounds, it is clear from comparing Figs. 1–3 with Figs. 5–7 that the environmental components of the marginal external cost (i.e. air pollution and carbon) are significantly lower than fuel taxes. This finding is in line with Newbery (2001) and Parry et al. (2014).

Also, Figs. 5–6 show that the structure of the marginal external cost does not differ significantly between petrol and diesel cars. In both cases, most of the marginal external cost of transport comes from congestion and accidents. Fig. 7 shows that most of the marginal external cost from HDVs comes from congestion and noise.

3. Corrective taxes

The idea behind a corrective or Pigouvian[17] tax is to internalize the externality by increasing the price, in this case, of fuel, so that its

[17] Corrective taxes are also known as Pigouvian taxes in honour of Arthur Pigou, a Cambridge Neo-classical economist, who also developed the concept of externalities.

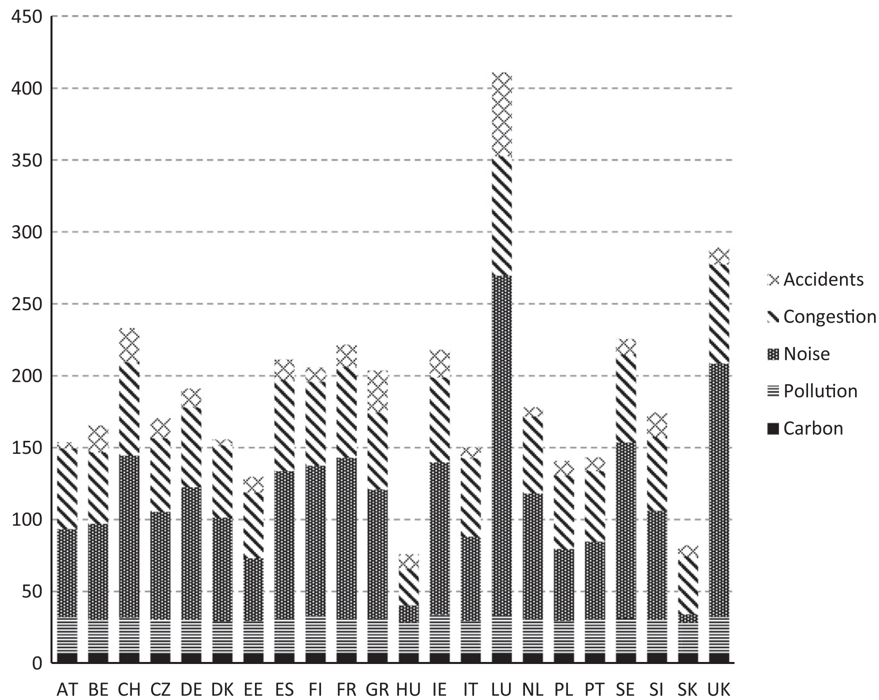

Fig. 7. Decomposition of the marginal external cost of HDVs, in €ct/L (2008 values and 2010 prices).

marginal private cost is equal to its marginal social cost. Since the marginal social cost is equal to the marginal private cost plus the marginal external cost, the amount of the Pigouvian tax is equal to the marginal external cost. Imposing a Pigouvian tax leads economic agents to take the whole cost of their actions into account when buying fuel (not only their private costs) and thus, to change their behaviour so that a socially optimal outcome can be reached.

The Pigouvian tax could take the form of an excise tax, i.e. a tax imposed on the seller, with the expectation that he would shift the burden on to consumers. The tax would not depend on sale price but on quantity sold.

The problem with trying to design fuel duties as Pigouvian taxes to internalize externalities is that they are not finely targeted instruments except for carbon emissions and to some extent, air pollution. Congestion and accidents are not well-represented by fuel consumption, and fuel taxes would essentially overcharge interurban car travel (Newbery, 2001). This problem has been highlighted by several authors already, including Parry and Small (2005), Newbery (1990, 2005b), and Parry et al. (2014), to name but a few.

Should we then wait until the different road transport externalities can be internalized with more sophisticated policies? The answer to this question is no, because fuel taxes can serve as a bridge until better designed measures can be put in place.

With this in mind, we now set to estimate fuel taxes that would at least go some way towards internalizing the different road transport externalities. A crude or naive tax designed in this way would be exactly equal to the marginal external cost, as computed in Table 6. However, this method would not be satisfactory because it would omit to account for the fact that when fuel consumption decreases because of increased fuel taxation, only part of this decrease is due to a decrease in distance driven. The other part comes from an increase in fuel efficiency (Parry, 2009; Parry and Small, 2005). This latter part does not help to internalize externalities which are distance related, it only internalizes externalities that are related to fuel consumption. The reduction in distance travelled results from a combination of reduced use of existing vehicles and reduced car ownership.

In order to take the above into account we follow Parry (2009), who defines a parameter, β, which represents the proportion of the reduction in fuel consumption that comes from a reduction in distance driven. More formally, β is defined as:

$$\beta = \frac{dM}{dt^T}\frac{dt^T}{dF}\frac{1}{f} \quad (5)$$

where M is distance travelled, F is fuel consumption, and t^T is the total tax on fuel (we assume that the producer price of fuel is constant, so that all price variations come from variations in fuel tax). For the sake of simplicity, β is assumed to be constant and exogenous.

Following Parry (2009), the 'corrective' excise tax, t^C, is then

Table 6
Summary of the model parameters, their values and their sources.

Parameter	Description	Value	Source
η_F	Own-price elasticity of fuel consumption	−0.55 for cars; −0.25 for HDVs	Parry and Small (2005, p. 1283) for cars; Parry (2009, p. 17) for HDVs
β	Proportion of the reduction in fuel consumption that comes from a reduction in distance driven	0.5 for cars; 0.6 for HDVs	Parry (2009, p. 9) for cars; Parry (2009, p. 17) for HDVs
η_f	Elasticity of fuel efficiency with respect to fuel price	−0.275 for cars; −0.1 for HDVs	Equation (9)
f^0	Initial fuel efficiency	Country and fuel specific	Odyssee
p^0	Producer price of fuel	Country and fuel specific	IEA (2013)[a]
t^0	Initial total tax on fuel	Country and fuel specific	IEA (2013)
VAT	Value Added Tax	Country specific	IEA (2013)

[a] IEA (2013) *Energy Prices and Taxes* has a table for each country, and the relevant values for each country were used.

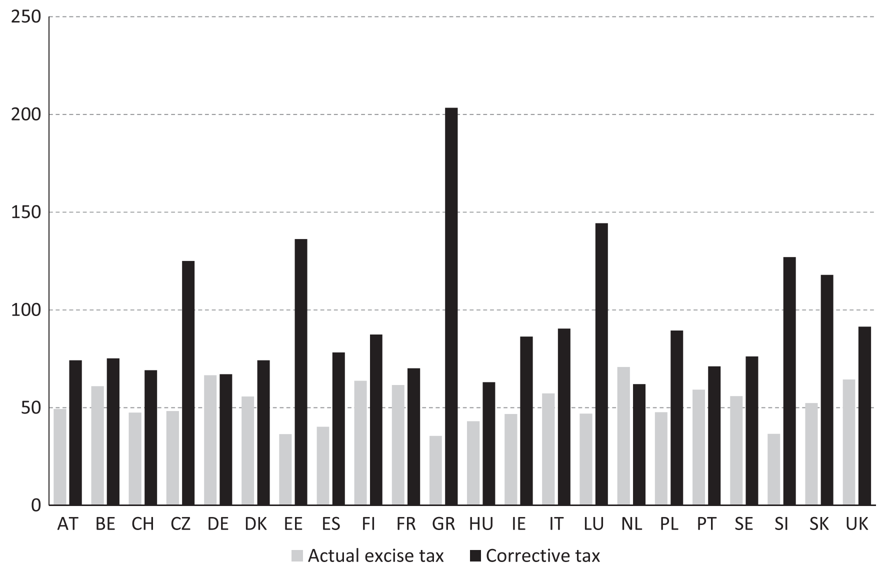

Fig. 8. 'Corrective' and actual excise petrol taxes, in €ct/L (2008 values and 2010 prices). Note: The 'corrective' tax takes into account the effect of fuel taxation on fuel efficiency. Source for actual excise tax: IEA (2013).

defined as being equal to the *corrected* marginal external cost, i.e. the marginal external cost where the distance related components are multiplied both by fuel efficiency and β. This is an adjustment for the fact that fuel consumption is not the direct source of the externality: only the reduction in distance driven matters from an externality correction perspective. Not multiplying by β would be equivalent to considering that all reduction in fuel consumption comes from a reduction in distance travelled, which is not true. The excise tax is therefore defined as:

$$t = E^{P_F} + f\beta(E^{P_M} + E^C + E^A + E^B) \tag{6}$$

where t is the excise tax on fuel, E^{P_F} is the carbon externality, f is fuel efficiency, β is the proportion of the reduction in fuel consumption that comes from a reduction in distance driven, E^{P_M} is the air pollution externality, E^C is the congestion externality, E^A is the accident externality, and E^B is the noise externality. E^{P_M}, E^{P_F}, E^C, E^A and E^B are assumed to be constant, in line with Parry (2009) and Parry and Small (2005).

We also need to take into account the fact that fuel efficiency is a function of fuel price (Parry, 2009). Knowing that fuel price is, by definition, equal to producer price plus total tax on fuel, if producer price is assumed to be constant and exogenous, then fuel efficiency depends on total fuel tax. Following Parry (2009) and Parry and Small (2005), we use a constant elasticity function:

$$f = f(t^T) = f^0\left(\frac{p^0 + t^T}{p^0 + t^0}\right)^{\eta_f} \tag{7}$$

where η_f is the elasticity of fuel efficiency with respect to fuel price, p^0 is the producer price of fuel, t^0 is the initial total tax, f^0 is the initial fuel efficiency and t^T is the total tax on fuel. The total tax on fuel, which includes excise tax and Value Added Tax (VAT), can be expressed as:

$$t^T = t + (p^0 + t)VAT \tag{8}$$

where t is the excise tax.[18] This relationship is not used for diesel consumed by HDVs because diesel for commercial use is exempt from VAT in every European country (IEA, 2013).

η_f can be estimated using β and the own-price fuel elasticity, which we denote η_F:

$$\eta_f = -\eta_F(1-\beta) \tag{9}$$

Following Parry (2009) we assume that all elasticities are constant. We solve Eq. (6) numerically for each country.[19] We compute, for each possible value of the excise tax, t, the value of f, and then the value of $E^{P_F} + f\beta(E^{P_M} + E^C + E^A + E^B)$. Then, we subtract t from this value to obtain the net effect of the tax. The 'corrective' tax, t^C, corresponds to the value of t for which the net effect is null.[20]

One of the main purposes of taxation is to raise revenues for the government. The pure tax element of fuel taxes is, inevitably, distortive, but also needed to finance government expenditure. This is the reason why we add a VAT component to the 'corrective' tax. The VAT is country specific, so we use each country's VAT rate in our analysis. To compute the total 'corrective' tax, $t^{C,T}$, we use Eq. (8) but replace t with the 'corrective' excise tax, t^C:

$$t^{C,T} = t^C + (p^0 + t^C)VAT \tag{10}$$

Table 6 summarizes the parameters of the model, their values and their sources.

3.1. Results and discussion

Figs. 8–10 show the 'corrective' and actual excise petrol and diesel taxes for cars and HDVs. Figs. 11–12 show the same taxes with VAT as well. This last exercise is not done for HDVs because they are exempt from VAT. Figs. 13–15 show the ratio between the actual and 'corrective' excise tax on petrol and diesel for cars and HDVs. It should be emphasized that, as already highlighted above, these 'corrective' fuel taxes we estimate are far from perfect instruments to internalize noise, congestion and accident externalities and they can only be seen as a temporary measure until perfect charging can be implemented.

The striking result is that, if fuel taxes were meant to fully internalize all road transport externalities, then fuel taxes would need to be increased in a number of countries.[21] As highlighted throughout

[18] Note that VAT applies to both the pre-tax price and the excise tax.

[19] We use Excel to do this.

[20] The excise tax values we tried range from 0 to 300 ct€/L, with consequent net effects ranging from very negative to very positive values.

[21] If the UK DECC (2015a) value for non-traded CO_2e emissions had been used instead of the US IAWA (2013) SCC, the 'corrective' tax for both petrol and diesel would have been about 11 to 12 ct€/L higher on average for all 22 countries.

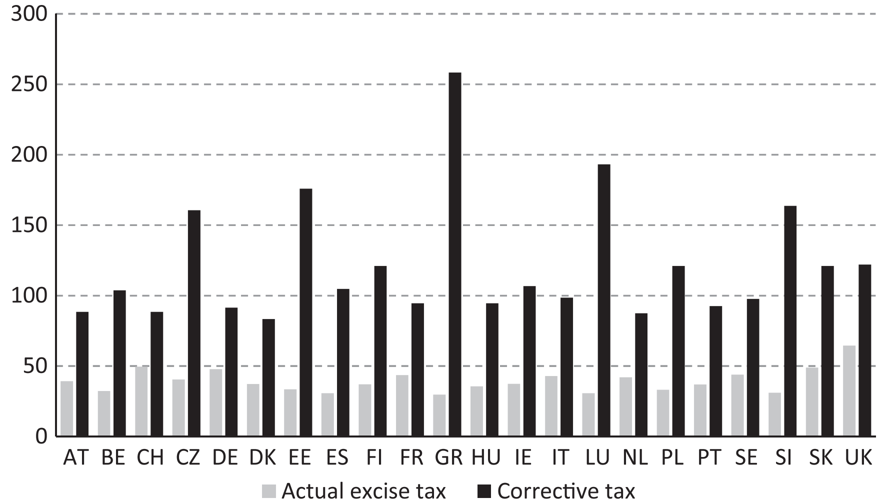

Fig. 9. 'Corrective' and actual excise diesel taxes for cars, in €ct/L (2008 values and 2010 prices). Note: The 'corrective' tax takes into account the effect of fuel taxation on fuel efficiency.
Source for actual excise tax: IEA (2013).

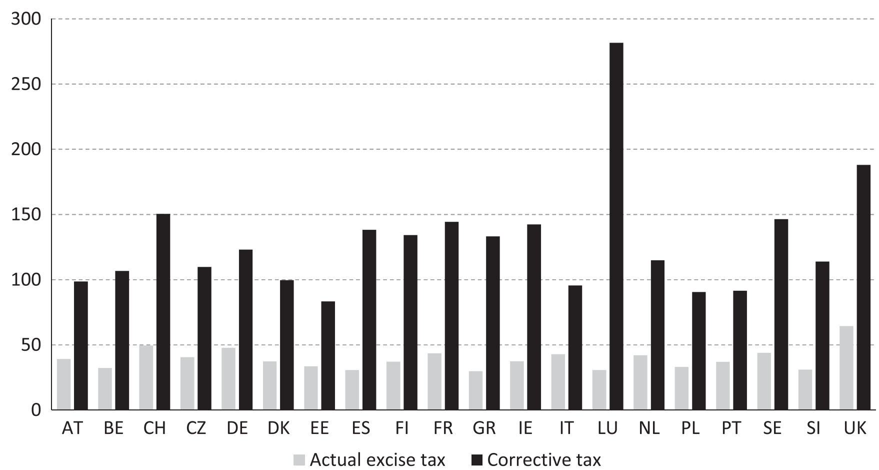

Fig. 10. 'Corrective' and actual excise diesel taxes for HDVs, in €ct/L (2008 values and 2010 prices). Note: The 'corrective' tax takes into account the effect of fuel taxation on fuel efficiency.
Source for actual excise tax: IEA (2013).

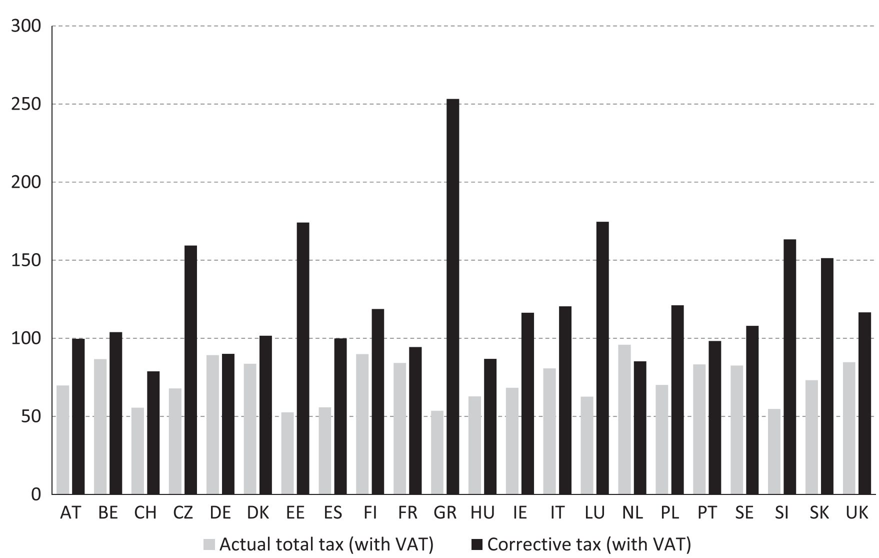

Fig. 11. 'Corrective' and actual excise petrol taxes plus VAT, in €ct/L (2008 values and 2010 prices). Note: The 'corrective' tax takes into account the effect of fuel taxation on fuel efficiency.
Source for actual excise tax: IEA (2013).

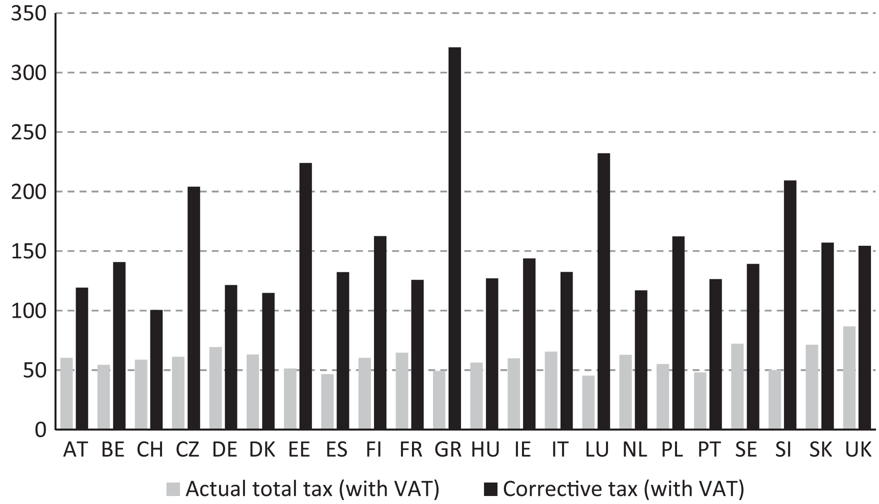

Fig. 12. 'Corrective' and actual excise diesel taxes plus VAT, in €ct/L (2008 values and 2010 prices). Note: The 'corrective' tax takes into account the effect of fuel taxation on fuel efficiency.
Source for actual excise tax: IEA (2013).

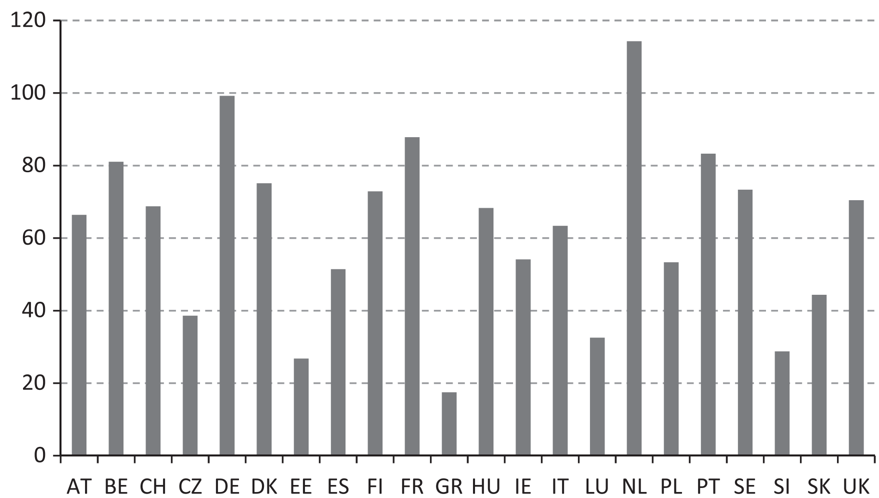

Fig. 13. Ratio between the actual and 'corrective' excise tax on petrol, in %.

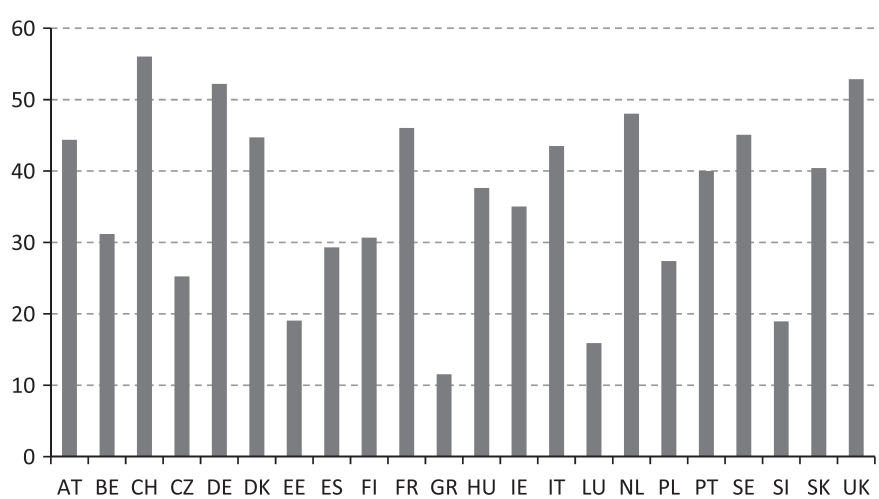

Fig. 14. Ratio between the actual and 'corrective' excise tax on diesel, for cars, in %.

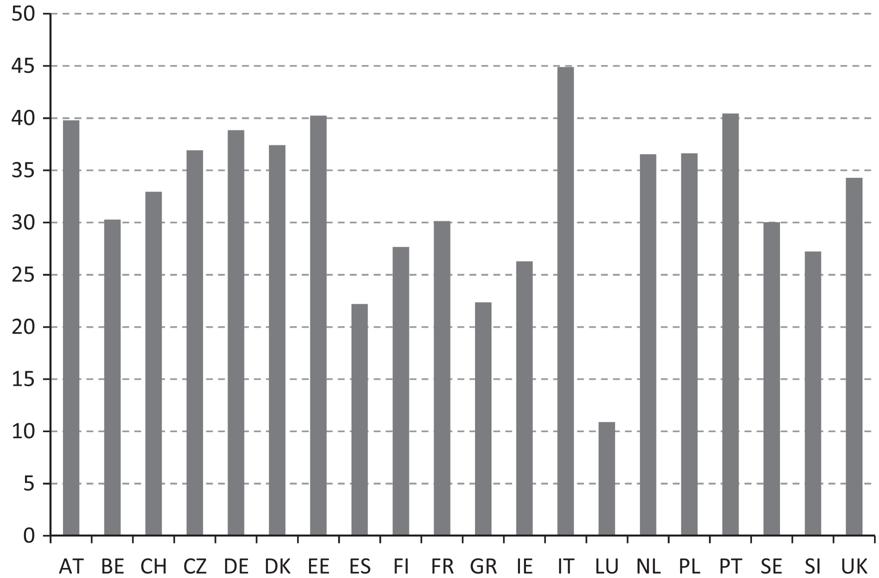

Fig. 15. Ratio between the actual and 'corrective' excise tax on diesel, for HDVs, in %.

the paper, fuel taxes are very imperfect instruments to internalize congestion and accidents, which actually make the bulk of the external costs from road transport,[22] and therefore the results presented here should be taken as a warning that in many countries road transport externalities are not currently internalized, rather than as a policy recommendation to increase fuel taxes. The internalization of externalities could be attempted with a fuel tax increase as a bridge or first step, but ideally, governments should eventually consider charges better targeted at congestion and accidents. In particular, the high congestion costs presented in Tables 3 and 5 underscore the case for transitioning to much more efficient instruments, such as peak period road pricing, as the resulting welfare gains could swamp those from raising fuel taxes. Similarly, accident costs would be better internalized with pay-as-you-drive insurance.

By inspecting Figs. 8–15, it is clear that the differences between the 'corrective' and the current excise tax are more pronounced for diesel than for petrol. In some countries the current petrol tax covers or almost covers most transport externalities, with ratios between current and 'corrective' taxes over 70%. These countries are the Netherlands, where the current tax represents over 114% of the 'corrective' tax,[23] Germany, Belgium, Portugal, France, the UK, Finland, Sweden and Denmark.

The countries where road transport externalities from petrol cars seem to be problematic, as they are not even close to being internalized by petrol taxes, are Greece, Estonia, Slovenia, Luxembourg and the Czech Republic. Congestion and accident costs in these countries are amongst the highest in the sample, and petrol taxes are amongst the lowest, thus yielding a highly inefficient combination.

For diesel consumed by cars, the differences between 'corrective' and current taxes are larger because of the higher fuel efficiency of diesel relative to petrol, which increases the cost of distance related externalities when expressed per litre of fuel consumed. In Switzerland, the UK and Germany, the current diesel tax is just over 50% of the 'corrective' tax. In the remaining countries the diesel tax is under 50% of the 'corrective' tax, and the problem is, like in the case of petrol, particularly acute in Greece, Estonia, Slovenia, Luxembourg and the Czech Republic.

Finally, the gap between 'corrective' and actual taxes is highest for diesel consumed by HDVs. In Luxembourg, the actual diesel tax is just over 10% of the 'corrective' tax. The reasons for this are that the diesel tax is the second lowest in the sample and at the same time, the external costs caused by HDVs in Luxembourg are amongst the highest, mainly due to a larger proportion of HDV traffic taking place on what can be classified as urban roads. Italy, Portugal and Estonia have the smallest gaps, yet the current tax only represents 40% of the 'corrective' tax.

Parry et al. (2014) find that for a number of countries included in the present study, current taxes are higher than 'corrective' taxes, but they caveat that result by stating that reductions in fuel taxes may not be efficient in practice because their 'corrective' taxes may have been underestimated for a variety of reasons (p. 141).

In addition, Parry et al. (2014) do not analyze diesel cars and diesel HDVs separately. This is sensible from a practical point of view, given that it would be impossible to charge different tax rates for the same fuel used by different vehicle types, as it would be fairly easy to cheat the system. The richness of carrying the analysis out separately consists in understanding how far off diesel users are from internalizing the externalities they impose on other vehicles and the rest of society. And the answer is that HDVs are paying less for their externalities than diesel cars.

One important conclusion from this analysis is that if fuel taxes were meant to internalize road transport externalities there would be room for re-structuring fuel taxation across our 22 European countries, and probably in other countries not included in this study as well.

In reality, however, most countries have additional vehicle registration and usage taxes, which may go some way towards internalizing road transport externalities. In addition to that, given that congestion and accidents are the main drivers of external costs, it would seem appropriate to finally take action and implement policies targeted at those externalities, such as congestion charges and pay-as-you-drive insurance. If there were insurmountable public and political opposition, then an increase in fuel taxes would certainly be in order, at least after taking into account any other road and vehicle taxes and charges in place on a country-by-country basis.

Future lines of research include combining 'corrective' fuel and vehicle taxes, as well as other road user charges, such as congestion charges, in order to understand how they could be jointly designed to internalize negative externalities.

[22] This finding is in line with Parry et al. (2014), who argue that 'much heavier taxation of gasoline is warranted... because of the combination of traffic congestion and traffic accidents' (p. 139).

[23] The current petrol tax more than covers the externalities from petrol cars in this case.

4. Conclusions

Using estimates of the marginal external costs of road transport from a number of EU-funded projects we computed 'corrective' fuel taxes that would internalize externalities in 22 European countries, allowing for the fact that fuel efficiency increases as a response to higher fuel taxes. The externalities we considered are climate change, air pollution, congestion, accidents and noise. If fuel taxes were meant to internalize all road transport externalities then there would be scope for increasing them in most of our 22 countries. Having said that, congestion and accidents contribute the most to the external costs of transport and fuel taxes are not efficient instruments to internalize these.

Under-taxation seems to be a problem especially for the case of diesel. For petrol, on the other hand, the results suggest that a number of countries are already on the right path, including the Netherlands and Germany, which have petrol taxes that cover all external costs, followed by Belgium, Portugal and France, where the ratio of the current tax to the 'corrective' tax is over 80%, and the UK, Finland, Sweden and Denmark, where the ratio is over 70%. The countries where petrol is under-taxed are Greece, Estonia, Slovenia, Luxembourg and the Czech Republic.

For diesel consumed by cars, the current tax is under 60% of the 'corrective' tax in all 22 countries. For diesel consumed by HDVs, the problem is severe. In Italy, Portugal and Estonia, for example, that have the smallest gap between the actual and 'corrective' tax, the current tax only represents around 40–45% of the 'corrective' tax.

Our 'corrective' tax attempts to internalize all externalities, assuming that fuel taxation is the only instrument used and no other taxes are in place. Different countries, however, have other road user taxes and charges, such as for example, vehicle registration and ownership taxes and to a much lesser extent, congestion charges. In addition, as highlighted throughout the paper, fuel taxes, although attractive because of their simplicity, do not target the bulk of the externalities efficiently. Demand for fuel may decrease but travel during peak times may not. With this in mind, the main finding of the present study is that road transport externalities in our 22 countries are not being internalized at present. The recommendation is that instruments should be devised to internalize them, and a first step for this could be an increase in fuel taxes, until the political will is there to press on with better tuned measures.

One caveat of this work relates to the accuracy of the estimates, which rely on data collected and methods developed by a number of EU-funded projects, as referenced throughout. Nonetheless, the results set a threshold. Thus, policy makers can get an idea of the order of magnitude and this can help them set priorities (Becker et al., 2012, p. 24; Parry et al., 2014, p. 165).

Future lines of research will seek to model fine-tuned policy instruments, 'fuel tourism' and equity aspects.

Fine-tuned policy instruments, which are likely to be congestion charges and pay-as-you-drive insurance, would need to be designed in combination with the already existing vehicle and fuel taxes.

'Fuel tourism', i.e. cross-border shopping of fuel, may result from different tax levels, which in turn affect final sale prices. HDVs, in particular, may refuel in countries where diesel is cheaper (Dreher and Krieger, 2010; Wlazlowski et al., 2009). Banfi et al. (2005), for example, estimate that about 9% of overall petrol sales in the Swiss border regions, neighbouring Italy, France and Germany, over the period 1985–1997, was due to fuel tourism from those three countries. A uniform diesel, and even petrol, final price (and tax) throughout Europe would erode any incentive for fuel tourism. This, however, would go against the efficiency principle of corrective taxes, which should vary across countries according to the externalities they are designed to correct. The problem is not trivial and certainly worthy of research.

Finally, another line for future work would entail understanding regressive impacts on consumers and competitive impacts on producers. Sterner (2012), for example, in a study of seven European countries, finds only weak evidence of regressivity, and when considering income over a lifetime, even this weak evidence disappears. He concludes that fuel taxes are approximately proportional to income. In contrast, in a study for the UK, Santos and Catchesides (2005), in line with Blow and Crawford (1997), find that when all households are considered, middle-income households suffer most of the burden, and when only car-owning households are considered, petrol taxation is strongly regressive. This is because low income households that own a car spend a larger proportion of their income on petrol. Regarding the negative impacts on producers, issues such as the structural inelasticity of HDV traffic should be taken into account. Rich et al. (2011), for example, highlight the absence or scarcity of substitutes and argue that, in order to be fully efficient, fuel taxes on commercial diesel should be implemented alongside investment in alternative transport modes, to encourage substitution towards transport modes generating fewer negative externalities. These problems are important but fall outside the remit of the present paper.

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