The impact of fiscal policies and standards on passenger car CO_2 emissions in EU countries

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Abstract

The most important weapons currently used against continuously increasing greenhouse gas emissions in passenger car transport are standards and taxes. Opposite to the CO_2 emissions standards for new cars which have been implemented at the EU level, fiscal policies implemented in EU countries are determined at the national level and are different across EU countries. In this paper we have discussed advantages and problems related to the implemented policy measures as well as interactions between different measures.
Keywords: passenger cars, policy, fuel tax, standards, rebound.

1 Introduction

Road transport which is primarily based on fossil energy is after power generation, the second biggest source of greenhouse gas emissions (GHG) in the EU. It contributes about one-fifth of the EU's total emissions of carbon dioxide (CO_2). The emissions from the road transport are continuously increasing over the last twenty years. Only exception was period between 2008 and 2010 when due to the economic crisis travel activity slowdown [1].

The largest part of the total GHG emissions of road transport is caused by passenger cars. Although fuel efficiency of passenger cars has been significantly improved in the last decade trends toward more powerful vehicles and additional services in cars have reduced impact of fuel efficiency improvements. At the same time vehicle ownership level is continuously increasing in all EU countries. These developments have significant impact on the EU's progress in cutting overall GHG emissions.

The most important measure for the reduction of GHG emissions at the EU level are the emission targets for new passenger cars. In the EU, different types

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of fiscal policy measures are implemented with the goal to promote environmentally friendly fuels and technologies as well as more fuel efficient vehicles.

The objective of this paper is to discuss advantages and problems related to the implemented policy measures as well as to explain interactions between different measures. It builds on Ajanovic and Haas [2, 3].

After the brief introduction, this paper provides an overview on recent developments in selected EU countries. In the third section current policies are documented and discussed. Special focus is put on standards and fuel taxes. A formal framework for the better understanding of the interactions between standards and fuel taxes is given in section four. Major conclusions complete this paper.

2 Recent developments in car transport in EU countries

In this section the major recent developments in car transport in selected EU countries are documented. The focus is put on twelve EU countries (Austria, Denmark, Finland, France, Germany, Greece, Italy, The Netherlands, Portugal, Spain, Sweden and United Kingdom) for which most of data have been available.

Figure 1 shows the development of stock of passenger cars per capita in selected countries for the period 1990–2012. It can be noticed continuously increasing car ownership level in all countries. In 2011 the lowest car stock per capita was in Spain (0.36) and highest in Italy (0.62).

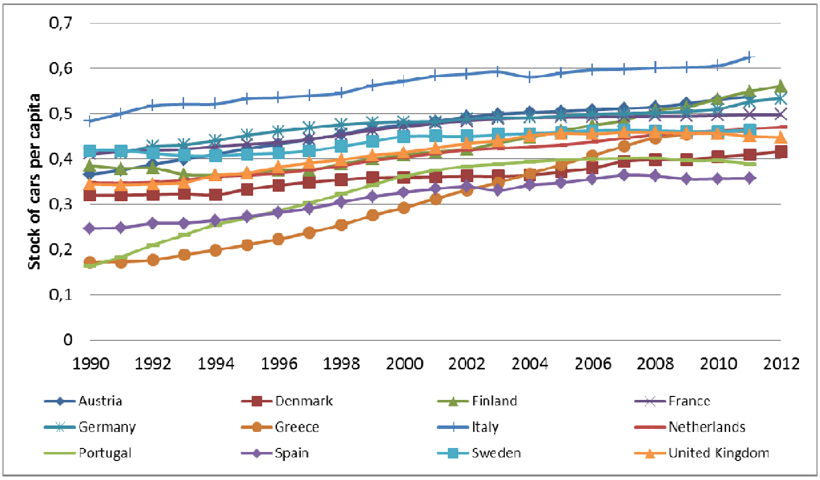

Figure 1: Stock of passenger cars per capita (data source: [4]).

Due to the implemented policy measures in the EU average specific energy consumption of cars has been reduced in the last decade. In 1990 average fuel intensity of passenger cars in analysed countries was between about 7.5 and 9.5

litres per 100 kilometres. Already in 2010 fuel intensity is in the range between 5.8 and 8.3 l/100 km (see Figure 2). However, the fuel intensity shown in Figure 2 is distorted because the shown fuel intensity has been diluted by more powerful cars leading to lower reduction of energy consumption per km driven. The impact of car size on fuel intensity is analysed by Ajanovic *et al*. [5].

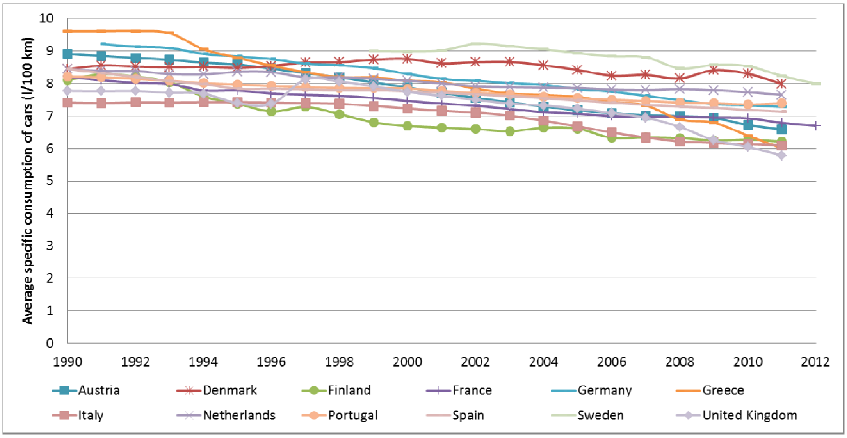

Figure 2: Average fuel intensity of passenger cars (data source: [4]).

The number of average kilometer driven per car almost all analyzed countries is slightly decreasing. Only in Spain and Portugal number of kilometer driven in period 1990–2011 has increased for about 500 km (see Figure 3).

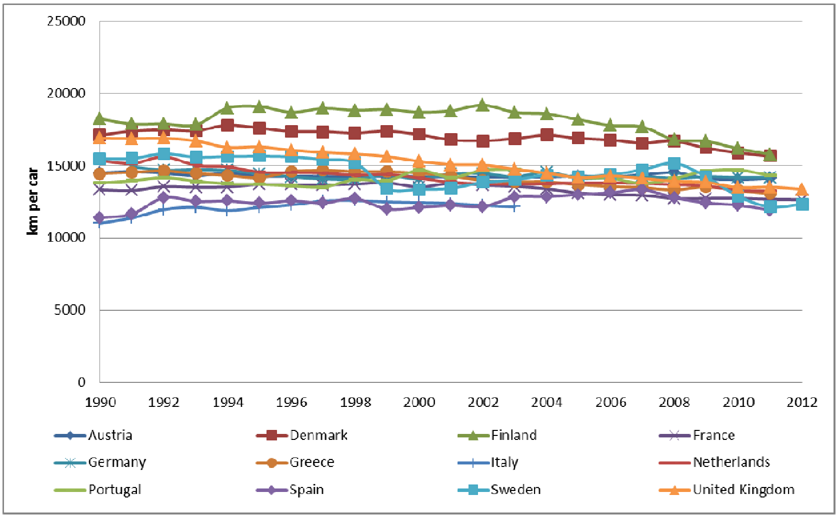

Figure 3: Average kilometer driven per car (data source: [4]).

Due to the EU emission targets CO_2 emissions from new passenger cars have been significantly reduced in the last decade. Figure 4 shows development of CO_2 emissions of new passenger cars for period 1995–2012. In all analyzed countries considerable emissions reductions have been achieved. In 1995 average emissions of new cars have been in the range from 224 (Sweden) and 175 (Spain) gCO_2/km. In 2012, the lowest emissions were in Portugal (117 gCO_2/km) and the highest in Germany (142 gCO_2/km). The strongest decrease can be noticed after 2008.

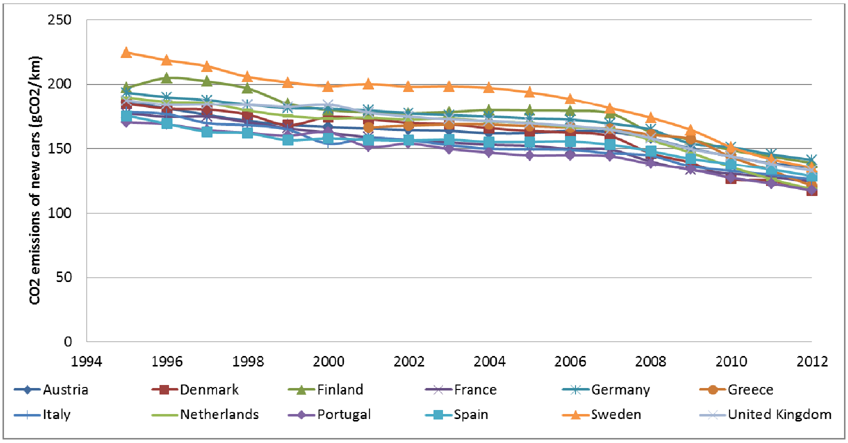

Figure 4: Average CO_2 emissions of new passenger cars (data source: [4]).

3 Currently implemented policies

To decrease carbon dioxide (CO_2) emissions from passenger cars, many countries have adopted different policies to reduce the emissions of new cars. Most important policies used nowadays are standards for CO_2 emissions rates of new cars and fiscal policy measures such as fuel tax, car registration tax and car annual tax.

Standards for CO_2 emissions of new cars are set on the EU level and car manufacturers must meet the standards or pay penalties for noncompliance.

Opposite to standards fiscal policy, measures are determined at the national level, and they are very different across EU countries.

In this paper special focus is put on fuel taxes, since once car is purchased, this tax can still have an impact on driving behaviour.

3.1 Standards

In the scope of the EU Strategy to reduce CO_2 emissions from light-duty vehicles very important measure is the EU Regulation [6] on passenger cars. This Regulation is directly applicable in the Member States and does not need to be transposed into national law through national legal instruments. According to the

Regulation average CO_2 emissions from cars should not exceed 130 grams CO_2 per km by 2015 and should drop further to 95g/km by 2020. The 130 grams target will be phased in between 2012 and 2015 [1].

At first agreements with car manufactures have been on a voluntary basis. Since the first target of 140 gCO_2/km for 2008 was not meet on time (the average for the whole car market for 2008 was 153.7 g/km [7]), in 2009 the first mandatory CO_2 emission standards for cars were adopted in the EU (see Figure 5) [8]. Target for 2015 is 130 gCO_2/km, and for 2020 95gCO_2/km.

In practice this means that each manufacturer gets an individual annual target based on the average mass of all its new cars registered in the EU in a given year.

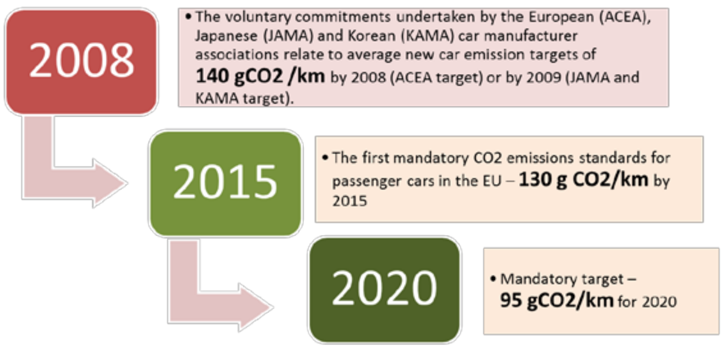

Figure 5: Emission targets for new passenger cars in the EU up to 2020.

Because only the fleet average is regulated, manufacturers are able to produce cars with emissions above their indicative targets if these are offset by other cars which are below their indicative targets. Indicative emissions are established for each car according to its mass on the basis of the emissions limit value curve (LVC) described in Annex I in the Regulation. This curve is set in a way that a fleet average of 130 grams of CO_2 per km is achieved for the EU as a whole [1].

The limit value curve for the 2015 target is calculated using following equation:

$$CO_{2\_SP} = 130 + \alpha \cdot (M - M_0) \quad (1)$$

where CO_{2_SP} are permitted specific emissions, M is a mass of car in kg, M_0 is 1289 kg, and a is the slope of the LVC (0.0457).

This curve is set in a way that compared to today; emissions from heavier cars have to be reduced more than those from lighter cars.

Since targets for 2015 and 2020 are mandatory, manufacturer will have to pay penalties if their average emission levels are above the target set by the limit value curve. The penalties will be based on the calculation of number of grams per kilometre (g/km) that an average vehicle registered by the manufacturer is above the target, multiplied by the number of cars registered by the manufacturer. A premium of 5 EUR per car registered will apply to the first g/km above the target, 15 EUR for the second g/km, 25 EUR for the third g/km, and 95 EUR for each further g/km. From 2019 every g/km of exceedance will cost 95 EUR [1].

Due to the implementation of mandatory CO_2 emissions standards, cars are expected to become more energy efficient – to consume less fuel per km driven.

However, reduced energy intensity lead to reduced energy service price (P_s):

$$P_S = P_E \cdot FI \tag{2}$$

where P_E is fuel price (EUR/l), and FI fuel intensity (l/100km).

Instead of FI oft is used fuel efficiency η:

$$\eta = \frac{1}{FI} \tag{3}$$

The service cost savings for car users usually lead to the change of driving behaviour. The behavioural response to the introduction of a new more efficient technology or other measures implemented to reduce energy use is called direct rebound effect (see also Section 4).

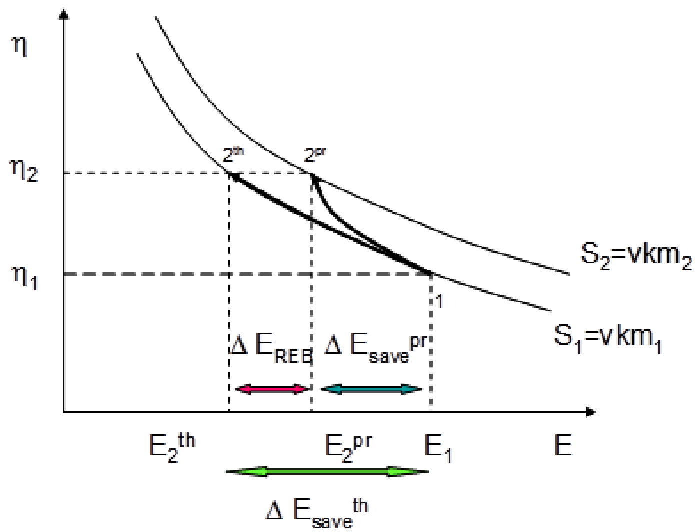

Figure 6: The rebound effect [9].

The basic principle of a rebound effect is shown in Figure 6. Point 1 shows the initial situation (E_1 – energy consumption, η_1 – fuel efficiency, S_1 – service, in this case vehicle kilometer driven vkm_1). With the increasing energy efficiency from η_1 to η_2 theoretically energy consumption could be reduced from E_1 to E_2^{th}. Due to the higher efficiency, service price is lower, which causes increase in service demand. Due to the increase in energy efficiency from η_1 to η_2 and the rebound effect energy consumption will be reduced to E_2^{pr} instead to E_2^{th} [9].

A CO_2 emission standard should lead to increasing fuel efficiency of new cars. This could reduce energy service price for car drivers and lead to change of the behaviour, e.g. cars are used more frequently and/or on longer distances. The resulting rebound effect can significantly reduce the impact of the implemented standards.

3.2 Fiscal measures

In opposite to CO_2 emission standards which are set on the EU level, implemented fiscal policy measures are established at the national level. Due to different national goals, these policies are very different across the EU. The mostly used taxes in car passenger transport are fuel taxes, registration taxes and annual ownership taxes. However, criteria for these taxes are very different in various EU countries.

Table 1: Taxes on acquisition and ownership (data source: [10]).

Country	VAT	Registration tax	Ownership tax
Austria	20%	Based on fuel consumption Maximum 16% + bonus/malus	Kilowatt
Denmark	25%	105% of DKK 15,500 + 180% on the remainder	Fuel consumption, weight
Finland	24%	Based on price + CO_2 emissions Min. 5%, max. 50 %	CO_2 emissions/ Weight x days
France	19.6%	Based on CO_2 emissions From € 100 (136 to 140g/km) to € 6,000 (above 200g/km)	None
Germany	19%	None	CO_2 emissions
Greece	23%	Based on cc + exhaust emissions 5%–50% Luxury tax up to 40%	CO_2 emissions/ cylinder capacity
Italy	21%	Based on kilowatt /weight/seats	Kilowatt, exhaust emissions
The Netherlands	21%	Based on price + CO_2 emissions	CO_2 emissions, weight
Portugal	23%	Based on cc + CO_2 emissions	Cylinder capacity, CO_2 emissions
Spain	21%	Based on CO_2 emissions From 4.75% (121–159g/km) to 14.75% (200g/km or more)	Horsepower
Sweden	25%	None	CO^2 emissions, weight
United Kingdom	20%	None	CO_2 emissions, cylinder capacity

Table 1 shows the criteria for the registration and ownership tax in some EU countries. Registration taxes are usually based on fuel consumption, CO_2 emissions, power or weight of car, car price, etc. Annual ownership taxes for passenger cars are mostly based on CO_2 emissions, power, cylinder capacity and weight. However, there are countries without registration taxes such as Germany, Sweden and United Kingdom, or without ownership tax such as France.

Value Added Tax (VAT) in the analysed countries is in the range from 19% in Germany and 25% in Sweden and Denmark.

The differences in registration taxes and VAT lead to different car prices in the EU countries. Figure 7 shows car retail prices in twelve EU countries for three different car types (small, medium and large car). The price difference is mostly due to different taxes.

In contrast to a registration tax which can impact the choice of cars, fuel tax could have an impact on the short-term driving behavior (e.g. travel activity, switch to other transport mode, etc.). How a fuel tax works is shown in Figure 8.

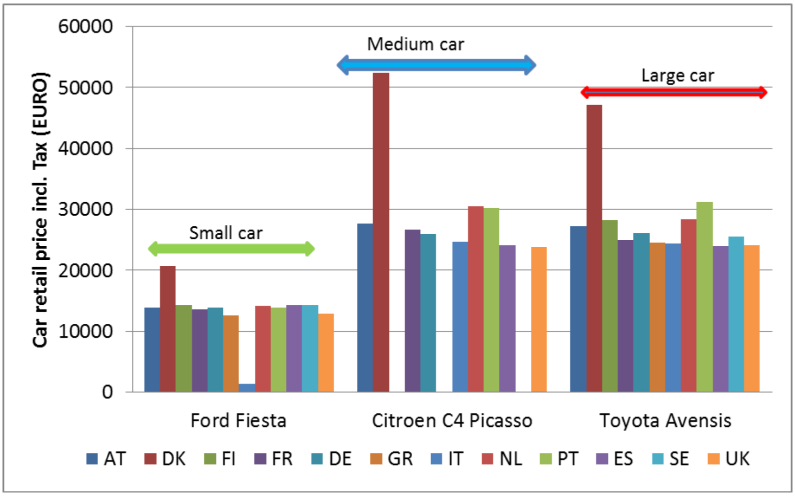

Figure 7: Car retail prices including taxes in 2011 [11].

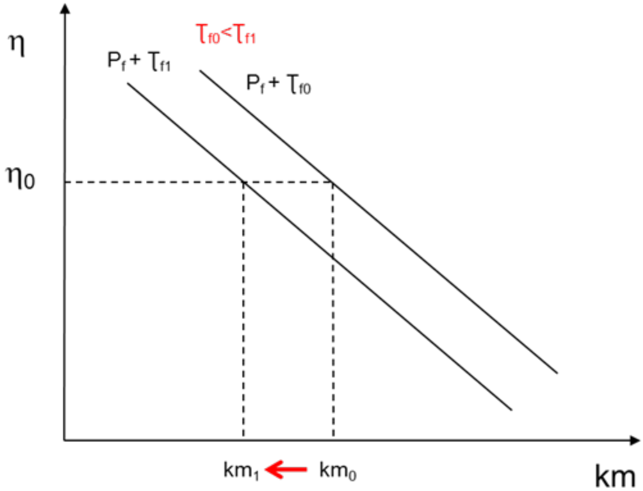

Figure 8: How fuel taxes works.

With the increasing fuel tax in the case of unchanged car efficiency (η_0) the number of kilometer driven will be reduced. However, currently a fuel tax is policy measure designed primarily to increase governmental revenues [12]. Reduction of CO_2 emissions is a secondary motive.

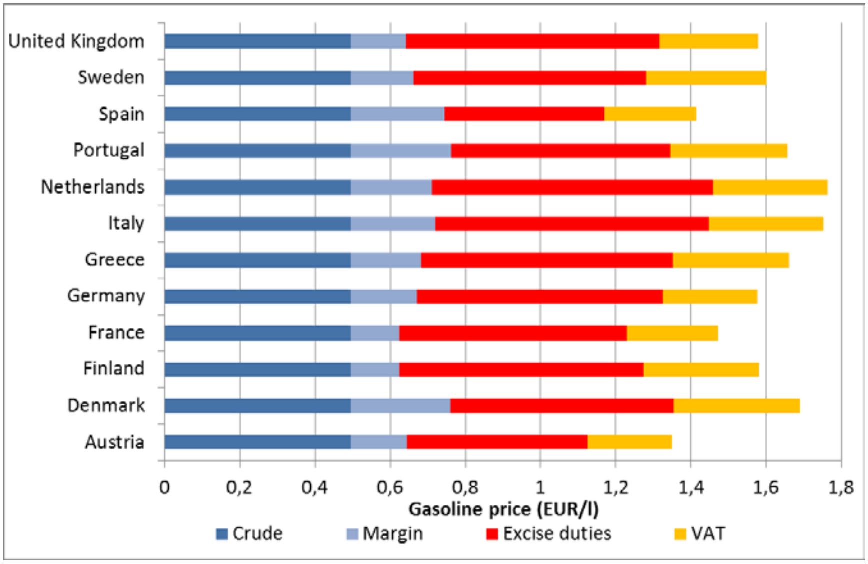

Figure 9: Composition of gasoline prices including taxes in 2013 [13].

In Figures 9 and 10, gasoline and diesel prices in different EU countries are shown. For the analyzed countries total tax on gasoline is in the range from 47% (Spain) to 61% (Finland). Tax on diesel is slightly lower, between 42% (Spain) and 57% (United Kingdom).

The impact of fiscal policies is dependent on available income. Transport fuel taxes as % of GDP are shown in Figure 11. It can be noticed that in the period 2003–2011 in all analyzed countries transport fuel taxes have been actually slightly reduced in relation to GDP, the only exception is Greece.

In the case of environmental taxes (taxes related to the ownership and use of motor vehicles) the situation is very different in analyzed countries. Comparing to 2003 in 2011 environmental taxes (excl. fuel taxes) as % of GDP have been decreased in seven countries and increased in five (see Figure 12).

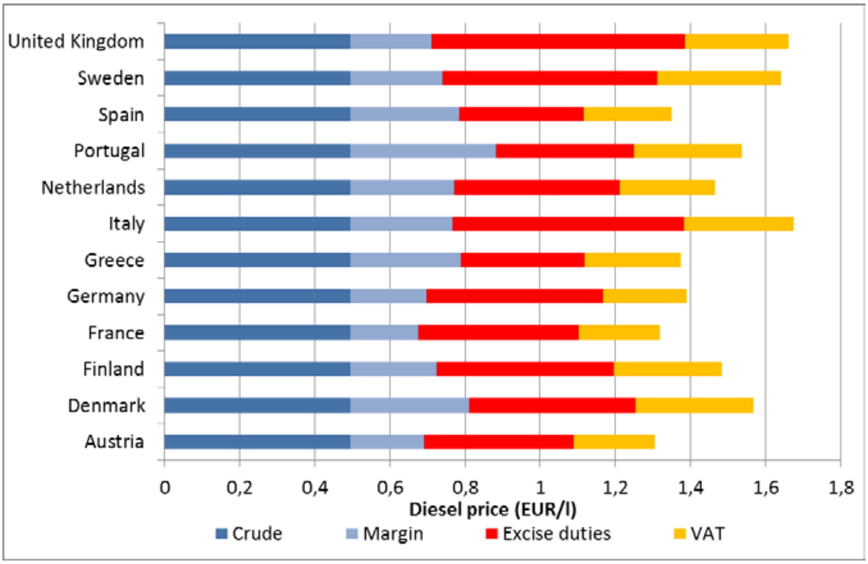

Figure 10: Composition of diesel prices including taxes in 2013 [13].

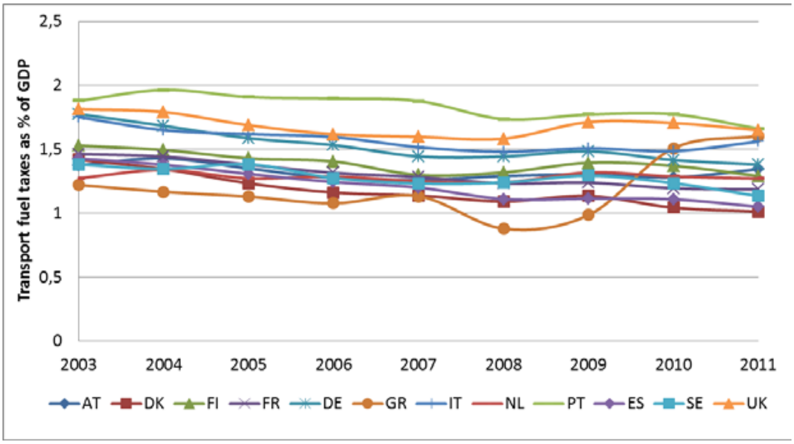

Figure 11: Transport fuel taxes as % of GDP (note: transport fuel taxes include those taxes which are levied on the transport use of fuels/energy products) [14].

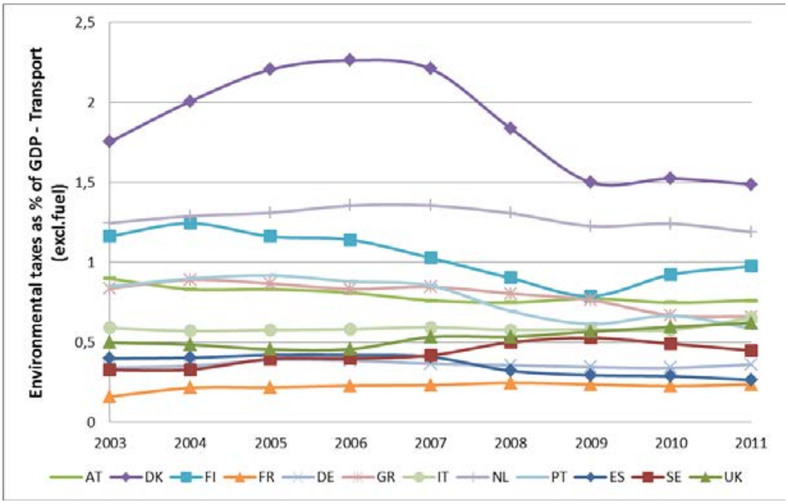

Figure 12: Environmental taxes as % of GDP – Transport (excl. fuel) (note: Transport taxes (excl. fuel) mainly include taxes related to the ownership and use of motor vehicles) [14].

4 Standards vs. taxes: formal framework

In this section we describe the formal framework used to assess the effects of standards versus fuel taxes on energy consumption as well as the interactions between these instruments. This framework builds on [2], [3] and [9]. For a better understanding the major basic equations are repeated here.

The basic relation between energy consumption (E), total vehicle kilometres driven in a country (vkm), and average fuel intensity (FI) is given in Eq. (4) for the starting point 0:

$$E_0 = vkm_0 \cdot FI_0 \tag{4}$$

In the case that a standard for maximal fuel intensity (FI_{max}) is introduced, theoretical saving due to a standard is:

$$\Delta E^{th} = vkm_0 \cdot (FI_0 - FI_{max}) = vkm_0 \cdot \Delta FI \tag{5}$$

However, due to the cheaper services after the improvement of fuel intensity energy saving will be reduced because of the rebound effect (see also Figure 6).

$$\Delta E^{pr} = \Delta E^{th} - \Delta E_{REB} \tag{6}$$

with:

$$\Delta E_{REB} = FI_{max}(vkm_1 - vkm_0) \tag{7}$$

Using the definition of the service price elasticity:

$$\alpha_{vkm,P_s} = \frac{\frac{\Delta vkm}{vkm}}{\frac{\Delta(P_E FI)}{P_E FI}} \tag{8}$$

the difference in vkm driven caused by the rebound effect is calculated as:

$$\Delta vkm_{REB} = \alpha_{vkm,P_s} vkm_1 \frac{\Delta(P_E FI)}{P_{E0} FI_{max}} \tag{9}$$

where $\alpha_{vkm,Ps}$ is the elasticity of vehicle kilometres driven with respect to service price P_S.

Using previous equations and the fundamental definition described in Greene [15], the elasticity of energy consumption with respect to a change in fuel intensity is derived (for detail see [16]):

$$\gamma_{E,FI} = \frac{\frac{dE}{E}}{\frac{dFI}{FI}} = 1 + \alpha_{vkm,P_S} \tag{10}$$

From Eq. (10) it can be seen that the elasticity of energy consumption with respect to a change in fuel intensity ($\gamma_{E,FI}$) is one plus the elasticity of energy service (in our case vkm) with respect to service price (Ps).

Figure 13 depicts the effect of a fuel tax versus standard depending on service price elasticity. For example, if a tax in the magnitude of 1% is introduced and the price elasticity is (-0.3) then the energy saving effect is 0.3%. If standard in the magnitude of 1% is introduced and the price elasticity is e.g. (-0.3) then the energy saving effect is 0.7% and the rebound effect due to more km driven is 0.3%.

The principle of how a fuel tax versus a standard works in depicted in Figure 14. It shows the changes in efficiency (η), energy consumption (E) and service price (Ps). In the case of the unchanged efficiency (η_0), the increasing tax leads due to increasing service price (Ps_τ), to the reduction in energy consumption (ΔE). If a standard is implemented efficiency will be improved from η_0 to η_1. This will lead to the reduction of energy consumption. However, due to a lower service price Psη this saving effect is lower than theoretically possible (ΔEη).

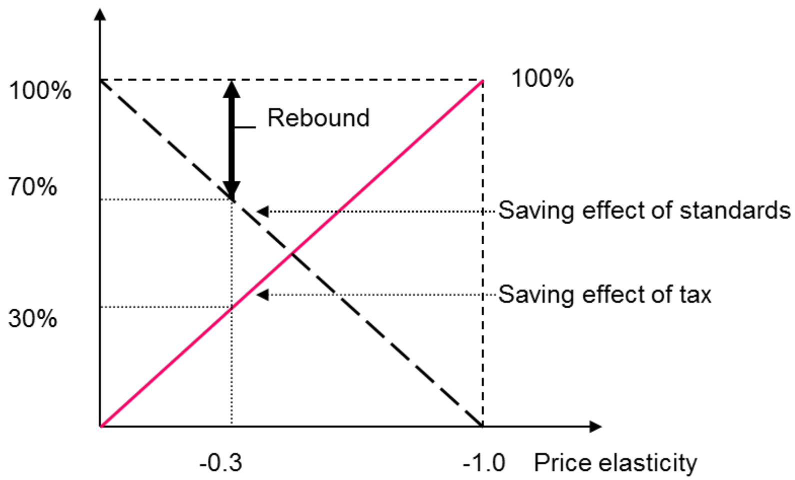

Figure 13: Effect of a tax vs. standard depending on service price elasticity [2].

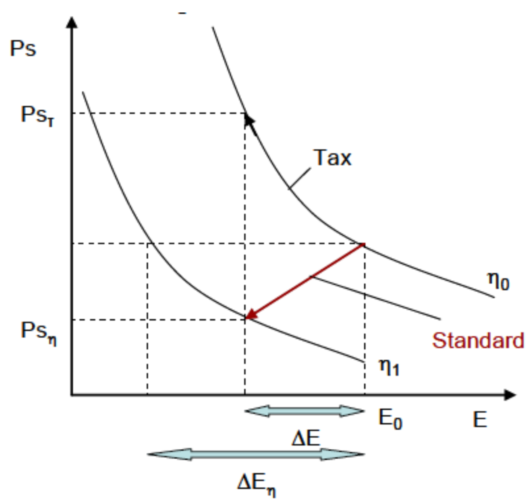

Figure 14: Fuel tax versus standard [2].

Finally we analyze how a registration tax (τ_{R_CO2}) that depends on the nominal specific CO_2 emissions (CO_{2_SP} (kg CO_2/km)) of a car works.

The relation between specific CO_2 emissions and fuel intensity is given in Eq. (8):

$$CO_{2\_SP} = f_{CO_2} \cdot FI \tag{11}$$

and correspondingly

$$CO_{2\_SP\_max} = f_{CO_2} \cdot FI_{max} \tag{12}$$

where f_{CO2} is fuel specific emission factor (in kg CO_2 per liter of fuel).

A CO_2 based registration tax leads to purchase of cars with lower specific CO_2 emissions per km driven. Figure 15 depicts the relation between a registration tax and the nominal specific CO_2 emissions (see also Section 3.1). The higher the registration tax is the lower are the specific CO_2 emissions of the average sold cars. For every required standard $CO_{2\_SP\_Max}$ a corresponding tax ($\tau_{R\_CO2\_max}$) could be implemented to meet this standard (see example in Figure 15).

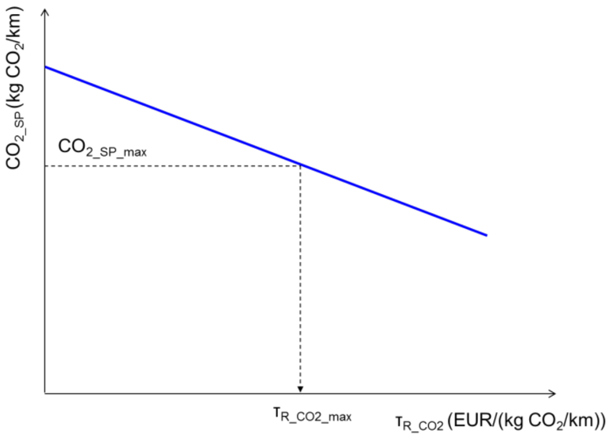

Figure 15: Relation between a registration tax (τ_{R_CO2}) and the nominal specific CO_2 emissions (CO_{2_SP}).

Remark: the relationship between a registration tax and the nominal specific CO_2 emissions will also depend on the elasticity of investment costs.

Hence, in principle a CO_2-based registration tax works like a standard and leads to the same effect – lower service price for driving and a direct rebound effect due to more km driven – as a standard (see Figure 16).

Empirical analyses of the magnitude of price elasticities have been conducted in many papers (e.g. [17–19]). Investigations conducted by the authors of this paper (see e.g. [2, 3, 16]) have resulted in long-term service price elasticities of about (-0.4) to (-0.45). Related to the above reflections this leads to the following interpretations: the effect of 1% increase in fuel prices due to a fuel tax would result in energy savings of about 40% to 45%. With a standard which decreases CO_2 emissions by 1% the savings would be between 0.55% and 0.6%. About the same effect would come due to a CO_2-dependent registration tax.

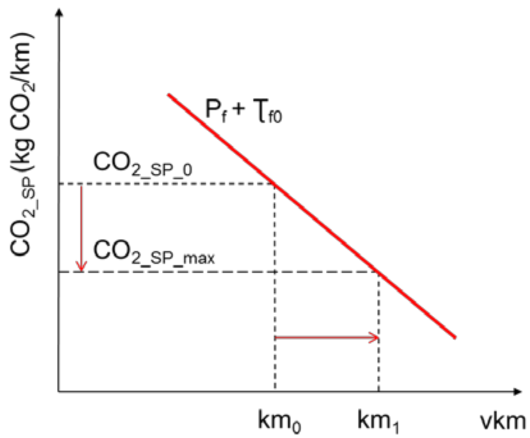

Figure 16: Relation between the nominal specific CO_2 emissions and the vehicle km driven.

5 Conclusions

For the realisation of the EU targets regarding the reduction of CO_2 emissions a simultaneous introduction of different policy measures is required. The rebound effect due to increasing fuel efficiency and resulting decreasing service price could be reduced with fuel taxes, see Figure 14. However, CO_2 emission reduction targets are set at the EU level and they are the same for all EU countries while taxes are regulated at the national level. As a result in the EU there is a broad portfolio of implemented taxes as well as on criteria of their implementation. A harmonization of fuel taxes in EU countries and their adaptation to the CO_2 targets could contribute to the reduction of the negative impacts of the rebound effect.

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