Rates of CO_2 Registration Taxes Levied on Passenger Cars in the EU – Can They Cause Distortion?

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Abstract:

Some of the European Union member states try to tackle the issue of CO_2 emissions generated by the transport sector through environmental registration taxes. The aim of the present research is to ascertain whether they use distorting and unfair parameters represented, in particular, by graduated progressive rates. Tax parameters consisting of average and marginal rates, taxes or nominal rates for 26,100 cases are calculated for various CO_2 emission levels in passenger cars. We determine the optimal shape of such parameters from the point of grades, shape and progression and we identify differences from the optimum in the monitored countries. It was discovered that from the 13 countries of the European Union that use vehicle registration tax on passenger cars based on CO_2 emissions, only Austria applies a tax that approximates the optimum. In five countries, we identified imperfections consisting of the graduated nature or local or global decrease in the rates examined. Registration taxes in the remaining countries are basically incompatible with the requirement of non-distortion. Even those taxes that do not generate significant revenues and are less socially sensitive, as is the case with the environmental registration tax, must be designed in a manner that is fair and non-distorting.

Key words: Registration Tax; CO_2 Emissions; Distortion; Graduated Progression.

JEL classification: H21; H23.

1 Introduction

External costs of transport are mainly generated through local air and soil pollution, global air pollution, traffic congestion and accidents, exposure to noise and the need for infrastructure maintenance (Santos, 2010). Carbon dioxide is a substance with a major global impact on air quality; it causes permanent and irreversible climate change with serious consequences, which has been confirmed through widely accepted results of Cramer et al. (2001), Pastor and Post

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(1998), or Manabe and Wetherald (1980). Due to the fact that the automotive industry will predominantly use traditional technologies at least until the year 2030 (Proost, 2009), the situation has to be addressed.

Therefore, the level of carbon dioxide produced should be included in the taxation of vehicle operation, which is in line with the recommendation proposed by Leicester (2005), Nordhaus (2006), Stern et al. (2006), Parry at al. (2007), Sallee (2011), Johnson et al. (2013). Moreover, the above requirement corresponds to institutional objectives of the European Union ensuing for example from the White Paper on Transport (European Commission, 2011), Decision No. 162/2013/EU (European Commission, 2013), Regulation No. 691/2011 of the European Parliament and of the Council (European Parliament and Council of the European Union, 2011) or Decision 2015/1339 (Council of the European Union, 2015). The mentioned requirements are also in accord with the United Nations goals, included in particular in the United Nations Framework Convention on Climate Change (United Nations, 1992) or the Kyoto Protocol (United Nations, 1997) and closely correspond to goals formulated by the Organisation for Economic Cooperation and Development (2011).

One of the tax instruments used in EU countries to factor the road transport externalities is vehicle registration tax, which in certain countries is applied in the form of a tax on carbon dioxide. It is clear that registration tax, unlike tax on vehicle ownership, does not take into account the different periods of vehicle use and, similar to the tax on ownership, does not address the parameters of actual operation (when the vehicle is parked in a garage, it cannot generate emissions) (David and Montag, 2014). Registration tax only factors the nominal parameters of the vehicle, not the actual generated emissions.

Though taxes, through the setting of their parameters, can take into account the externalities involved, they may simultaneously also generate undesirable market influences referred to as distortions. One of the fundamental tax distortions is the negative impact on the market through graduated rates. It is apparent that the system based on grades causes market inequity and distortion (David, 2015). The question is whether the carbon registration tax in the individual EU countries is designed as distorting or not. The aim of the research is to find out whether the rates of carbon registration tax in EU countries are flexible or graduated with possible distorting impacts on market entities. The research shall result in the evaluation of the environmental registration tax in EU countries the ensuing recommendations for the potential adjustment of registration tax parameters in these countries or a suitable design of the tax to be introduced in the other EU countries so that the remaining countries do not have to search for inspiration in the distorting design of registration tax.

2 Literature review

Cnossen (2005) maintains that significant externalities should be quantified and the less significant consequences may be disregarded. This view corresponds to the second best approaches to taxation. In practice it is very difficult, costly and even impossible to determine the social costs of environmental pollution; this is a reason to apply the second best solutions (Gandhi and Cuervo, 1998). Therefore, policy makers should set the goal of socially acceptable quality of the environment and determine tax and other instruments to achieve that goal. Such solution may be assisted by the second best fiscal instrument in the form of vehicle registration tax based on the value of the indicator of environmental pollution in the form of carbon dioxide emissions. This indicator is utilised in the tax base for passenger cars in 13 EU countries.

Private utility and social utility was first distinguished by Pigou (1920), who introduced the issue of externalities into economic theory. The adjustment, construction and parameters of the purely corrective first best tax, addressing the issue of externalities, were dealt with by many scholars, e.g. Buchanan and Stubblebine (1962), Meade (1952), Cunningham (1960), Sandmo (1975), and others. According to Sandmo (1975) corrective taxes can only be useful if appropriately designed.

Besides purely corrective taxes and their modifications, there are also multi-purpose types of corrective taxes referred to as environmental taxes, which were formulated and examined by Goulder (1995, 2000) or Fullerton and Metcalf (1997). The research results of the above authors suggest that in an open, dynamic economy where demand and supply are highly related and respond to reciprocal signals, taxes on externalities should be designed and incorporated into a complex, strongly interrelated economic system. Parry et al. (2012) note that according to modern views, environmental taxes of the Pigovian type have many imperfections and lack feedback from entities affected by the externality concerned. Kampas and Horan (2016) explain fundamental differences between the first best and second best environmental taxation and emphasise that environmental taxes as such, or in synergy with other taxes, may create significant market distortions.

The principle of distortion origination is simple. A heterogeneous tax burden causes distortions; the differences may stem from geographical aspects (Ye et al., 2018), or they may manifest themselves in varying taxation of financial market instruments (Landoni, 2018). Taxes can distort production as well as production rate of enterprises and result in incorrect investment allocation (Bethmann et al., 2018), cause excessive use of certain services (Fatica and Prammer, 2018), or determine labour mobility (Hilber and Lyytikainen, 2018). An unsuitably

designed system of taxation in the transport sector can result in the distortion of vehicle parameters that form the tax base. This causes distortion in the offer of and demand for vehicles without apparent reasons for preferences of technical or emission properties.

We often encounter other suggestions for tackling transport externalities that deform the market, such as those by Sergeant et al. (2008), who pro-pose introducing and increasing parking fees, transit charges or fees for entrance permits to certain locations.

Progressive taxation has long been known, which is evidenced for instance by the fact that Smith (1776) worked with this instrument. Progressive tax rate was primarily introduced for income taxes, but the instrument has spread across tax systems and is widely used for other taxes, too. An example is the environmental taxes, in particular registration tax paid on the purchase of a motor vehicle (ACEA, 2019, PwC, 2018). Blechová (2012) defines the progressive tax rate as tax that increases in grades and its average rate is lower than the marginal rate. This definition evokes the idea of graduated progressive tax rates. However, in case that only the tax base exceeding the limit of the previous tax bracket is burdened with the higher tax rate, we speak of a flexible progressive tax rate.

It clearly follows from the research of Pitelin (2018) that inequity and distortion effect of the tax can be caused through its graduated progression. In other words, the progressive tax rate cannot be fair and non-distorting if it has not been set as flexibly progressive.

This can be considered a general conclusion following from the current knowledge of tax distortions. Then it is apparent that the graduated rate of environmental registration tax on road motor vehicles is not fair and will cause market distortions, whether they are production distortions or consumption distortions, depending on the area of automotive industry where they originate.

3 Data and Methodology

The initial identification of negative effects of the graduated tax rate and the need to address transport externalities of CO_2 emissions through a tax instrument are based on the findings of other authors.

The graphic depiction of the model of optimal proportional and progressive environmental tax rate, which may be considered fair and non-distorting, will provided. This fairness does not exactly apply to specific rate setting, but rather to horizontal and vertical fairness of an average rate, marginal rate or tax or nominal rate of proportional or flexibly progressive tax rate on the local or global scale.

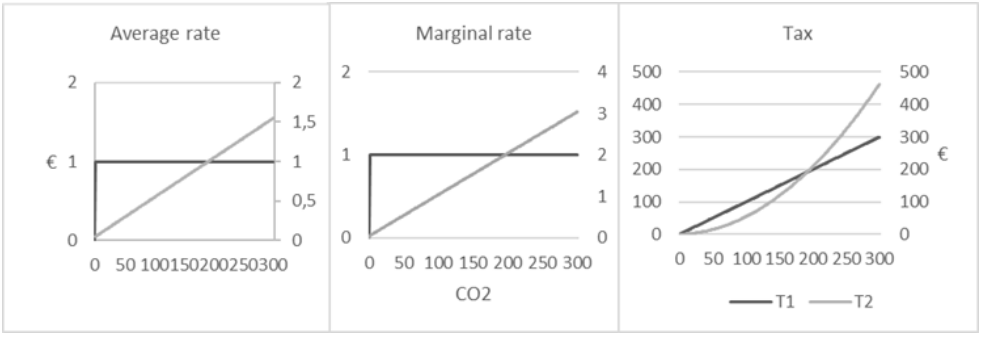
The sources of information about the registration tax parameters are summary publications containing relevant data published by the European Automobile Manufacturers Association (ACEA, 2019) and PricewaterhouseCoopers (PwC, 2018). Registration tax is applied in all member states of the European Union in various forms including the registration fee. Certain EU countries apply the parameter of CO_2 emissions in the calculation of registration tax. For these countries, we formulate the process of identifying the substantial parameters of registration tax based on CO_2 emissions, which are the subject of tax, the tax base and the tax rates. The national web portals focused on tax issues were used if more detailed information on the process of calculation of registration tax was needed.

For each country using the CO_2 factor in its registration taxes, the tax parameters are calculated separately for individual CO_2 emission levels by grams of the substance. According to practical calculations (Pelikán et al., 2018) made in the Copert program (Ntziachristos and Samaras, 2016, Davies Waldron et al., 2006), of all passenger cars it is the large, powerful SUVs with petrol engine in the emission class EURO IV that have the highest emissions, whose value is 277 g/km CO_2. Therefore, it makes sense to provide calculations for the values ranging from 0 to 300 g/km CO_2. For each country, there are at least 301 calculations (0-300 g CO_2) for each of the chosen parameters, which are the average rate, marginal rate and tax or nominal rate in case the calculation of the tax consists of other components besides that including the CO_2 emission factor. These other components were not included in the calculation. The above mentioned number 301 of calculations for each country is multiplied by the number of nuances in the calculations depending on the vehicle parameters in the form of age, type of fuel, EURO standard, volume of particulate matter PM, price of the vehicle and other environmental components of registration tax.

The situations where the increasing levels of CO_2 emissions are accompanied by volatility of or decrease in the average tax rate, marginal tax rate, amount of tax or nominal tax rate shall be identified as problematic in view of distortions and equity. The graphic depiction of the calculation results of these parameters of environmental registration tax shall reveal the mentioned problematic situations.

Necessary is to create a graphic representation of the models of optimal proportional and progressive environmental tax rate that can be described as fair and non-distorting.

Fig. 1 Parameters of optimal registration tax based on CO_2 emissions



Source: Authorial computation.

The optimal proportional average rate T1 is determined in such a way that its shape is accurate and constant, without any deviations, whereas the constant shape starts with the beginning of non-zero values of CO_2. The optimal progressive average rate T2 is flexible and its shape corresponds to a straight line throughout the interval from 0 to infinity. The optimal proportional marginal rate is constant and its constant shape starts with the beginning of non-zero values of CO_2. The optimal progressive marginal rate, similar to the optimal progressive average rate is flexibly rising and its shape again corresponds to a straight line throughout the interval from zero to infinity. The optimal proportional tax shows a constant increase. The optimal progressive tax rate shows a flexible progression, its shape is concave and it converges to a vertical. An important fact is that the setting of tax parameters is constant not only within the interval depicted, but at any level of CO_2 emissions.

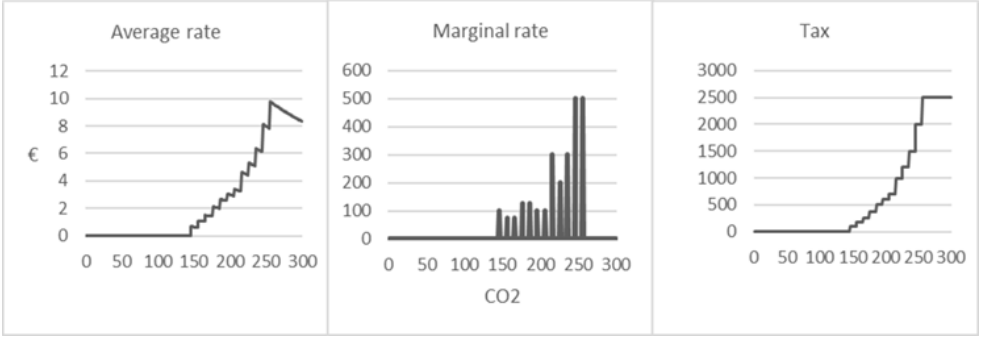
4 Evaluation of environmental registration tax based on carbon emissions in EU countries

Now we can identify and depict the actual shapes of average rates, marginal rates and taxes or nominal rates of CO_2 based registration tax components in the EU countries applying to this form of tax. Thirteen countries of the European Union include the value of CO_2 emissions specified in the registration certificate into the parameters of registration tax. These countries are Austria, Belgium, Croatia, Cyprus, Finland, France, Greece, Ireland, Malta, the Netherlands, Portugal, Slovenia, and Spain (ACEA, 2019). Other countries apply a simple registration fee (9 countries), which is not referred to as a tax, or its characteristics do not comply with the definition of a tax (David et al., 2018). Sixteen EU countries apply a tax whose base includes other than concrete emission parameters of the vehicle (PwC, 2018). Typically, these are the type of fuel, age,

engine capacity, engine power, or weight of the vehicle. There are also various combinations of the mentioned alternatives of registration tax and registration fee.

New as well as used cars, minibuses and motorcycles are subject to registration tax in Belgium. The tax is based on engine capacity and age of the vehicle in the entire country. Moreover, the Walloon region applies graduated environmental malus where CO_2 emissions exceed 145 g/km. Flanders uses a complex formula which includes the type of fuel, age, EURO standard and a correction factor in the form of CO_2 emissions. The tax rate increases with the engine power and decreases with the age of the vehicle.

Fig. 2 Parameters of environmental registration tax based on carbon emissions in Belgium



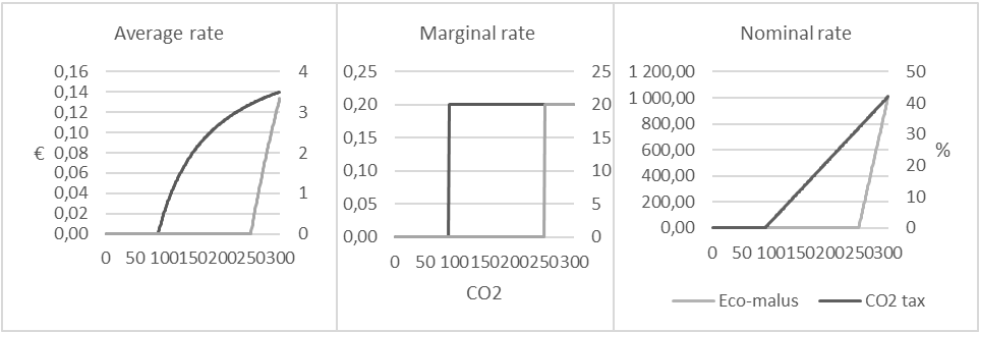
Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018), + Authorial computation.

The shape of the average rates of the tax corresponds to its graduated nature. There are 12 grades of tax rates according to the assigned band of CO_2 emissions in Belgium. The curve of average tax rate in Picture 1 shows that the setting of grades is not even. Beginning with 255 g CO_2, the average rate decreases and converges to zero. The development of marginal rates suggests that the taxation of additional emission units is very uneven. All units up to 145 g CO_2 are levied the zero-marginal rate. The zero rate also applies to individual grams of CO_2 located on the lower limit of the emission level grades. There is apparent progression of marginal grades along the entire curve of marginal rates; however, the progression is uneven. Tax on CO_2 grows in grade with the increasing value of CO_2 in the range of 145 to 255 g CO_2.

The tax in Belgium in term of its graduated nature and progression parameters is unfair and distorting. Significant deviations from the defined optimal shape of the average rate, marginal rate and tax were identified.

In Austria, registration tax is imposed on new passenger cars, minibuses, campervans and motorcycles from 125 cc or those not yet registered in the country. The tax is based on CO_2 emissions and selling price. The rate percentage is determined through a formula which includes CO_2 emissions, tax reduction and malus in case of high CO_2 emissions. Neither the tax reduction nor the malus apply to motorcycles. The maximum tax rate for motorcycles is 20 % of the selling price, and 32 % for other vehicles subject to tax. The rates are flexible. In case the purchase price parameter is unknown, it is suitable to depict the tax components individually.

Fig. 3 Parameters of environmental registration tax based on carbon emissions in Austria



Source: Based on data from ACEA (2019), PwC (2018), Federal Ministry of Finance – Republic of Austria (2019), David et al. (2018) + Authorial computation.

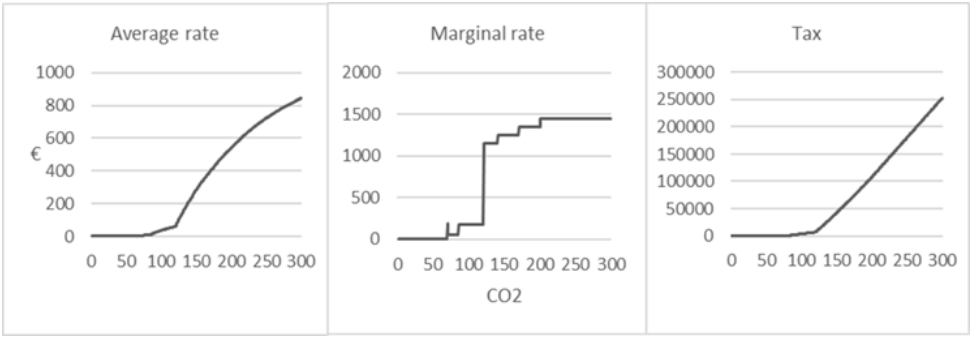
The average rate based on CO_2 is zero until 90 g CO_2 inclusive. It starts to grow from the value of 91 g CO_2 and its progression is flexible. This progression decreases with the growing value of CO_2 emissions and the shape of average rates is concave. Eco-malus is applied from the level of 251 g CO_2. The growth of its average value per emission unit is linear. The marginal rate of the carbon component of the tax is 20 % starting at 91 g CO_2. The situation is similar with the marginal rate of eco-malus, but its non-zero value of 0.2 € is applied from 251 g CO_2. Both the nominal rate and eco-malus have a linear, flexibly growing shape from the level of 91 and 251 g CO_2, respectively.

The registration tax system in Austria closely approximates the optimal model of CO_2 taxation. However, components of the registration tax applied in this country include distorting grades.

Registration tax in Croatia is paid on the first registration of a motor vehicle. The tax is based on the selling price, CO_2 emissions and type of fuel. The rate is always composed of two parts, of which one is graduated and the other one

is flexible. There is direct proportionality between the amount of the rates and the parameters concerned.

Fig. 4 Parameters of environmental registration tax based on carbon emissions in Croatia



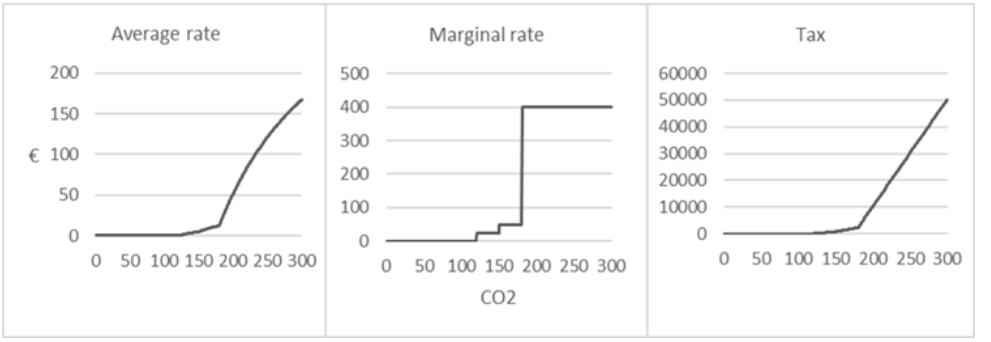
Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) + Authorial computation.

The overall shape of average rate, which is composed of a graduated and a flexible part, is flexible and concave. Both parts of the tax rate show the decreasing growth, divided into two sections at the breaking point of 120 g CO_2 emissions. The shape of the marginal tax rate is highly irregular. Its non-zero value starts at the level of 70 g CO_2 and then decreases and rises in grades. The highest grade is at the level of 120 g of emissions, followed by three grades at the levels of 140, 170 and 200 g CO_2. The total tax based on CO_2 flexibly grows; the growth is slower until 120 g and sharper from that point.

The tax in Croatia in term of its progression parameters is unfair and distorting. Deviations from the defined optimal shape of the marginal rate were identified.

Registration tax in Cyprus is levied on the registration of a new car or van, and a registration fee is also paid. The registration tax is based on CO_2 emissions in cars and on engine capacity in vans. The registration fee depends on CO_2 emissions and engine capacity. In relation to CO_2 emissions, the tax rate is flexibly progressive for cars and proportional for vans. The registration fee based on engine capacity is increasing and graduated.

Fig. 5 Parameters of environmental registration tax based on carbon emissions in Cyprus



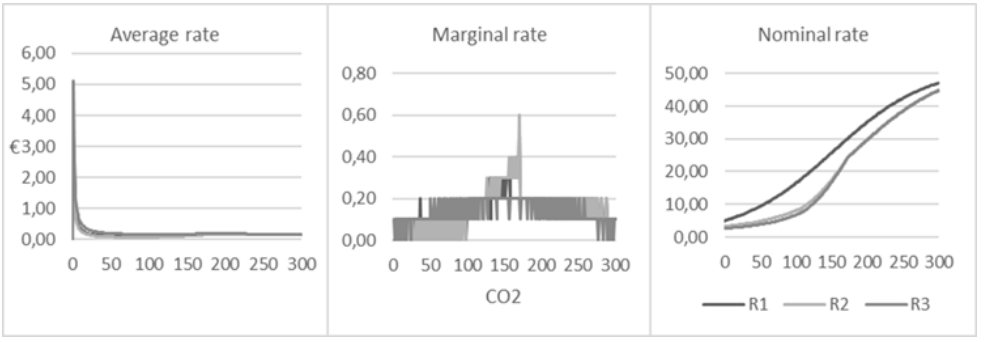
Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) + Authorial computation.

Due to the flexible setting of the nominal rate, the average rate is also flexible. The shape is concave and non-zero values start from 121 g CO_2 with a breaking point at the level of 180 g CO_2, when the average rate starts to grow faster. There is another breaking point at 150 g CO_2, which is, however, negligible in the graphic representation of the average rate. Three grades are apparent in the marginal rate depiction, whereas on the level of 180 g CO_2 it is the most significant. The total tax based on CO_2 shows a linear increase with the above mentioned breaking points, each of them marking more rapid growth of the tax.

The tax in terms of its graduated nature and progression parameters is unfair and distorting. Deviations from the defined optimal shape of the marginal rate were identified in the case of registration tax in Cyprus.

Finland levies tax on the first registration of passenger cars, vans, other vehicles up to 1 875 kg and motorcycles. The registration tax is based on CO_2 emissions, selling price (VAT inclusive) and age of the vehicle. The tax base for motorcycles consists of engine capacity and age of the vehicle. In relation to CO_2 emissions, the tax rate is progressive, and the same applies to vehicle age. The rate grows with age, which is divided by grades. In vans, the tax rate is reduced in grades depending on weight; the higher the weight, the higher the reduction of rate percentage. Motorcycles have an imposed tax rate according to engine capacity and growing age first degressively, then progressively and in the end degressively again.

Fig. 6 Parameters of environmental registration tax based on carbon emissions in Finland



Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018), Finnish Tax Administration (2019, 2019a) + Authorial computation.

Note: R1 = vehicles registered from 1 January 1958 to 31 December 2002; R2 = vehicles registered from 1 January 2003 to 31 December 2018; R3 = vehicles registered from 1 January 2019.

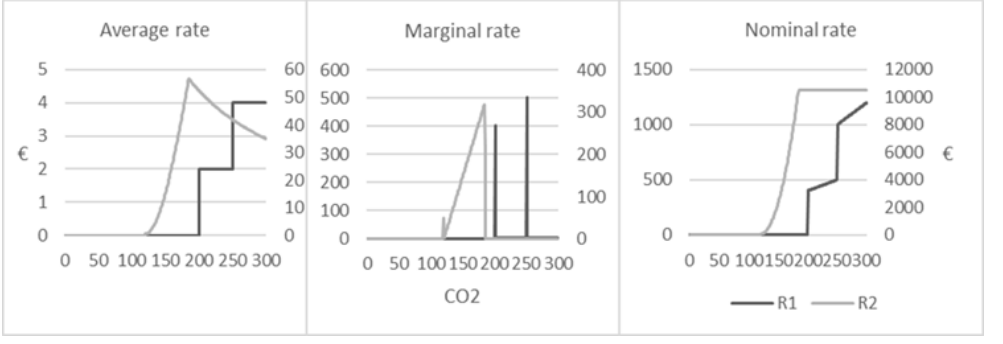
The average rates for passenger cars differ according to their age. The most significant are years 1958, 2003 a 2019, where the average rates show similar characteristics. First, they sharply decrease, then slightly increase and finally decrease again. Breaking points of the curve are 176 or 186 g CO_2 according to the vehicle age, and repeated drop at emission values of 215 or 323 g CO_2 according to the vehicle age. The breaking points at lower emission levels belong to older vehicles. The average rates are generally flexible and the convex shape changes to slightly concave. Because the rates have not been determined through calculation but are depicted in a chart, the marginal rates are graduated and highly fluctuate, although the chart shows many partial values. If local fluctuations are disregarded, global development of marginal rates is increasing and from the level of 170 g, CO_2 emissions begin to drop. The nominal rates for vehicles of all ages first rapidly grow and this growth slows down approximately at 180 g CO_2 depending on the vehicle age. The nominal rates are globally flexible regardless of the vehicle age.

Deviations from the defined optimal shape of the average rate and marginal rate were identified in the case of registration tax in Finland. This means that the tax is distorting and unfair.

France applies registration tax, or rather a fee and additional tax on vehicles with high emissions of CO_2. All vehicles on the first and any further registration are subject to registration tax. The additional tax applies to passenger cars with the first registration before 1 January 2008 on the first and any further

registration in France, and passenger cars with the first registration after 1 January 2008 only on the first registration in France, i.e. new or imported cars. Registration tax is based on engine capacity and regional specifics. The additional tax includes different parameters for vehicles first registered before and after 1 January 2008. Under Directive 70/156/EEC (Council of the European Communities, 1970), the tax base for vehicles registered before 2008 is the CO_2 value exceeding 200 g. In the case of other vehicles, the engine parameter is present in the tax base in the form of a formula using CO_2 emissions and engine power. The tax base of vehicles registered since 1 January 2008 is CO_2 value. The rates of registration tax vary by the region where the tax is collected. The additional tax rate for vehicles under Directive 70/156/EEC with the first registration before 1 January 2008 is graduated and depends on CO_2 values; for other vehicles registered before 1 January 2008 the tax is graduated according to the engine parameter in the form of the formula factoring CO_2 emissions and engine power. The additional tax rate for vehicles under EC Type Approval, first registered after 1 January 2008 is flexible and is calculated from CO_2 emissions exceeding 125 g CO_2. The additional tax rate for vehicles without EC Type Approval, first registered after 1 January 2008 is graduated according to the engine parameters in the form of a formula factoring CO_2 emissions and engine power. In the case of an imported vehicle with the first registration after 1 January 2008, the tax is reduced by 1/10 for every year of age.

Fig. 7 Parameters of environmental registration tax based on carbon emissions in France



Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) + Authorial computation.

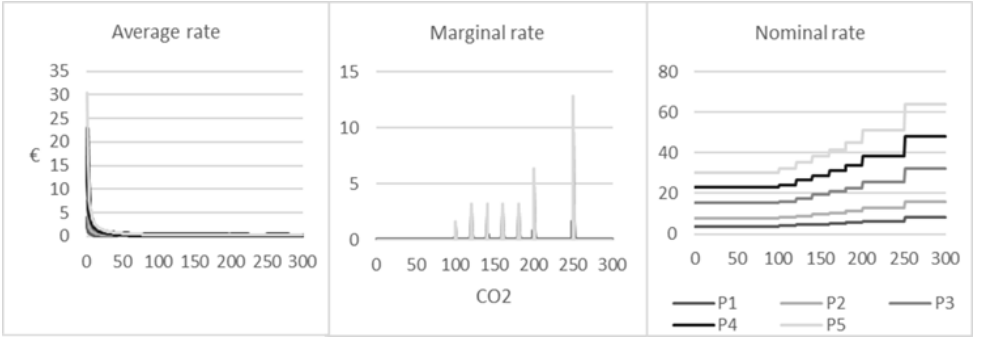
Note: R1 = vehicles registered before 1 January 2008; R2 = vehicles registered from 1 January 2008.

The average rate of tax on CO_2 emissions differs according to the age of vehicles with the breaking point in 2008. A higher maximum value of the average rate

is apparent for vehicles registered since 2008 taxed directly on CO_2 emissions. Its non-zero values start from 120 g CO_2 and increase sharply and flexibly in a convex curve. At the level of 185 g CO_2 there comes a turning point, where the average rate starts to decrease sharply and flexibly in a convex curve. In vehicles registered before 2008, taxed according to the HP parameter, which includes engine power and CO_2 emissions, the average rate becomes non-zero at 201 g CO_2 and its increase is graduated after 250 g CO_2. The shape of the marginal rate for newer vehicles contains two peaks. One is after reaching 120 g CO_2 and the other one is at 185 g CO_2. Beginning with that value, the marginal rate is zero. For older vehicles, there are also two peaks, at 200 and 250 g CO_2, around which the marginal rate is zero. The nominal rate for newer vehicles may be described as graduated and flexible. For older vehicles, the nominal rate is higher and its parameters are flexible from its non-zero values starting at 120 g CO_2 until its maximum at 185 g CO_2.

The tax in France in term of its graduated nature and progression parameters is unfair and distorting. Significant deviations from the defined optimal shape of the average rate, marginal rate and nominal rate were identified.

Fig. 8 Parameters of environmental registration tax based on carbon emissions in Greece



Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) + Authorial computation.

Note: P1 = price up to 14 000 €, P2 = price up to 17 000 €, P3 = price up to 20 000 €, P4 = price up to 25 000 €, P5 = price above 25 000 €.

The subject of registration tax in Greece is private passenger cars on the first registration in Greece, i.e. new and imported cars. Registration tax is based on taxable value represented by the selling price in the case of new cars. On imported cars, the tax base is represented by the value of the car at the time of starting operation, which is reduced in grades by age and type of the car and as the case may be, by high mileage (over 15,000 km per year). The tax rate

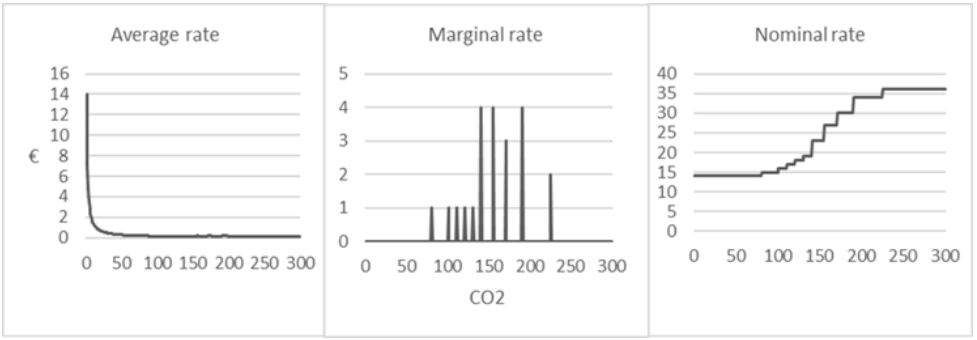
is graduated depending on the taxable value and increases or decreases in grades based on CO_2 emissions. Lower or higher tax rates are set similarly for vehicles with better or worse than standard emission values at a given time.

There are five average tax rates depending on the price band. All of them are high in the case of low CO_2 emissions and drop rapidly. Further development shows several slight increases with a subsequent bigger decrease. The higher the price of the vehicle, the higher the average rates. Marginal tax rates are zero except for seven emission values: 101, 121, 141, 161, 181, 201 and 251 g CO_2. The marginal rates assume irregular non-zero values at these points. Nominal rates clearly show differences in tax according to the price of the vehicle. Also the shape of nominal rates shows seven breaking points which account for the graduated increase of the nominal rates. The nominal rates remain stable in all price categories until the emission value of 100 g CO_2.

Also in Greece there were identified significant deviations from the defined optimal shape of the average rate, marginal rate and nominal rate. The tax in term of its graduated nature and progression parameters is unfair and distorting.

Registration tax in Ireland is levied on private as well as commercial vehicles of M1, N1 and N2 categories. The tax is paid on the first registration of the vehicle in Ireland and thus applies to new and imported cars. If an M1 vehicle is exported and registration tax is paid in another country, the original owner may claim repayment of the previously paid vehicle registration tax in Ireland. On new cars, registration tax is based on the market price of the vehicle. On imported cars, it is the market price of a similar car in Ireland. For M1 vehicles, the tax base consists of CO_2 emissions. For other categories, it is only the market price (N1) or the unit of the vehicle itself (N1 with less seats and all N2 vehicles). The tax rate for M1 category is determined by a percentage of the market price in grades, depending on graduated CO_2 emissions. For N1 vehicles, the tax rate is fixed and is calculated from the market price. For N1 vehicles with less seats and for N2 category, the rate is fixed and determined per vehicle.

Fig. 9 Parameters of environmental registration tax based on carbon emissions in Ireland



Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) + Authorial computation.

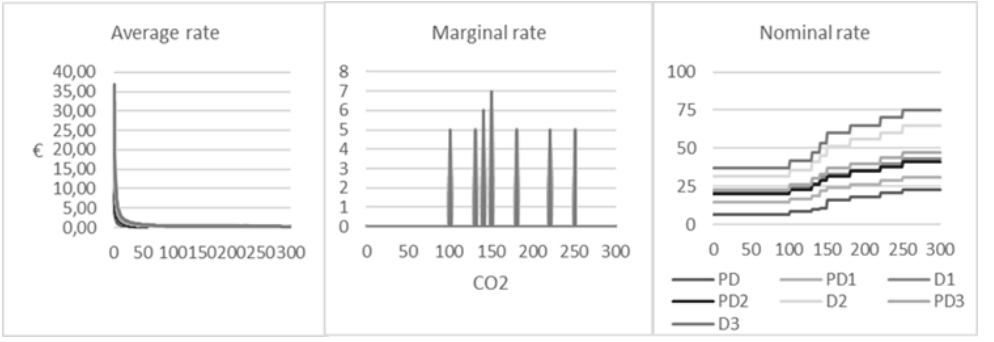
Average tax rates have a decreasing trend and converge to zero. There are several areas of increase in their shape, which are well-illustrated by the marginal rate indicator. The chart shows 10 peaks of different heights. These points are located at 81, 101, 111, 121, 131, 141, 156, 171, 191 and 226 g CO_2, in whose vicinity the marginal rates are zero. Nominal rates are proportional until 80 g CO_2 and then from 226 g CO_2. Grades of varied heights and ranges are apparent between these values.

The tax in term of its graduated nature and progression parameters is unfair and distorting. Significant deviations from the defined optimal shape of the average rate, marginal rate and nominal rate of registration tax were identified in Ireland.

The subject of registration tax in Malta is the first registration of new M1 vehicles and all registrations of commercial vehicles in all categories. Imports of M1 vehicles from third countries are also subject to tax. For M1 vehicles, registration tax depends on the selling price, CO_2 emissions, type of fuel, EURO standard, vehicle length and in the case of diesel engines, also emissions of particulate matter. Where information about emission standard is missing, the time equivalent of the emission standard is used. If M1 vehicles are imported, the tax base is formed by CO_2 emissions. The tax base of new commercial vehicles includes weight, engine capacity and EURO standard. The tax base of older commercial vehicles includes weight, engine capacity and EURO standard, reduced by grades according to the age and mileage of the vehicle. The tax rate for the M1 category is set partially by a percentage of the product of CO_2 and the price of the vehicle, where prices are differentiated for petrol drive, diesel drive with particulate matter emissions of up to 0.005 g/km incl. and diesel drive with particulate matter

emissions over 0.005 g/km. The other part is determined in grades by a percentage of the vehicle length and price. The rate for commercial vehicles is set as graduated by a percentage of vehicle weight and engine capacity depending on the vehicle category (M2, M3, N1, N2, N3) and EURO standard. In older vehicles, the rate is reduced in percentage grades with the growing age and mileage of the vehicle.

Fig. 10 Parameters of environmental registration tax based on carbon emissions in Malta



Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) +Authorial computation.

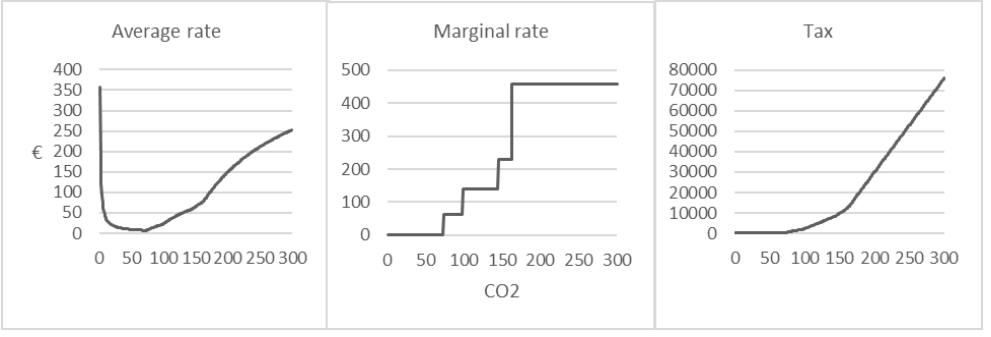
Note: PD = latest EURO standard petrol and diesel up to 0.005g PM, PD1 = latest EURO 1 standard petrol and diesel up to 0.005g PM, D1 = latest EURO 1 standard diesel above 0.005g PM, PD2 = latest EURO 2 standard petrol and diesel up to 0.005g PM, D2 = latest EURO 2 standard diesel above 0.005g PM, PD3 = latest EURO 3 standard petrol and diesel up to 0.005g PM, D3 = latest EURO 3 standard diesel above 0.005g PM.

The tax based on CO_2 in Malta is divided into seven categories according to the EURO standards and fuel type in synergy with the emission factor of particulate matter (PM). Average carbon taxes in Malta sharply decrease from the beginning of the shape and except for a few minor increases converge to zero. The above mentioned increases are well illustrated in the chart of marginal rates. There are seven increases altogether and their heights are the same except for the third and fourth peak. The marginal rate peaks are located at the levels of 101, 131, 141, 151, 181, 221 and 251 g CO_2. The rates are zero in the intervals around the peaks. The chart of nominal rates depicts the mentioned seven categories of vehicles. It also identifies grades of the tax rate and irregularities in intervals between the grades and in degrees of changes on the individual grades. The average rate is fixed in intervals from 0 to 100 and from 251 g CO_2.

In Malta there were identified significant deviations from the defined optimal shape of the average rate, marginal rate and nominal rate. The tax in term of its graduated nature and progression parameters is unfair and distorting.

The subject of registration tax in the Netherlands is the first registration of new and used private vehicles. Vehicle registration tax on new cars is dependent on CO_2 emissions. Used cars are taxed according to the catalogue price of the vehicle with degression based on the vehicle age. The tax rate for new private vehicles is flexibly progressive according to CO_2 value. For diesel vehicles, the tax rate is increased by the flat rate of 87.38 € per gram of CO_2 emission exceeding the value of 63 g CO_2. For used vehicles, the rate is a percentage of the catalogue price and flexibly degressive based on the vehicle age.

Fig. 11 Parameters of environmental registration tax based on carbon emissions in the Netherlands



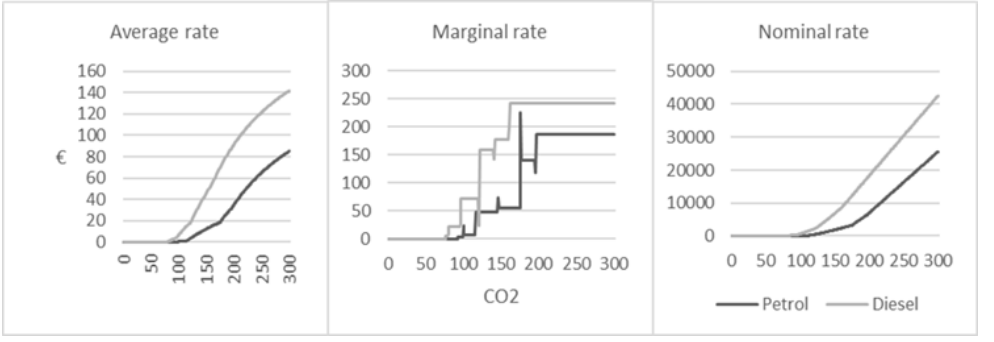
Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) + Authorial computation.

The shape of the average rate based on CO_2 is determined by the fixed amount and progression of the flexible part. The fixed amount causes high values of the average rate at the beginning of the monitored interval. The repeated growth is attributed to the increasing component of the tax. The decrease turns into the increase at the level of 74 g CO_2. The shape of the identified progression is concave. The increase of the average rate is thus getting slower. The marginal rate is ever increasing and there are no peaks around which the rate would be zero. Four grades apparent in the shape of the marginal rate suggest an equal number of changes in the taxation of the respective units of CO_2 emissions. The carbon tax is growing, whereas the growth accelerates upon reaching the levels of 74, 99, 145 and 163 g CO_2.

The tax in the Netherlands in terms of its progression parameters is unfair and distorting. Deviations from the defined optimal shape of the marginal rate were identified.

The subject of registration tax in Portugal is the first registration of new and used vehicles of all categories. The vehicle registration tax is based on CO_2 emissions and engine capacity. If CO_2 specification is unavailable, only engine capacity is considered. For motorcycles, the tax is determined according to engine capacity. The tax rate for new vehicles is uniformly progressive based on engine capacity and differentiated based on CO_2 value for petrol and diesel vehicles. The rate of tax on used vehicles is equal to that on new vehicles; however, it is subsequently reduced in percentage grades with the ageing of the vehicle. The tax rate is graduated for motorcycles.

Fig. 12 Parameters of environmental registration tax based on carbon emissions in Portugal



Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) +Authorial computation.

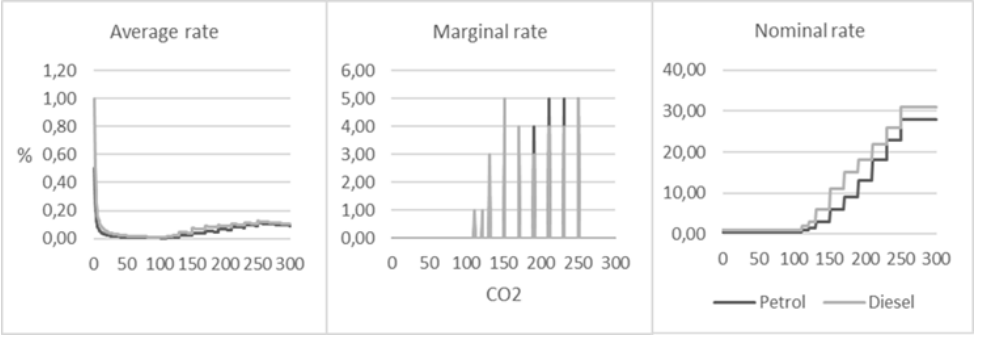
The differentiation of rates in Portugal is based on the differentiation of tax on CO_2 according to the fuel type. The average tax rate for both types of fuel increases, whereas non-zero values for petrol drive commence at 93 g CO_2 and for diesel drive at 77 g CO_2. The shape is concave in both cases and the growth of the average rate slows down with the increasing value of CO_2. The marginal rates suggest an unstable development for petrol as well as diesel drives. There are turning points, where the marginal rate increases and suddenly decreases and vice versa. There is no apparent regularity in the shape of this indicator except for the growing trend. The marginal rates grow until 197 g CO_2 for petrol drive and 162 g CO_2 for diesel drive. The highest marginal rate for diesel is at the point where CO_2 emissions reach 176 g CO_2. The nominal rates increase with the growing value of CO_2. At the same emission level, the rates

are lower for petrol vehicles, which fact is caused by the later start of non-zero rate and slower increase of the tax until 176 g CO_2.

The tax in term of its graduated nature and progression parameters is unfair and distorting. Deviations from the defined optimal shape of the marginal rate were identified in the case of registration tax in Portugal.

The subject of registration tax in Slovenia is the first registration of new and used vehicles of all categories. The tax base is the selling price of the vehicle or the customs value in the case of registration of an older vehicle. The tax rate is graduated and forms a percentage of the selling price or customs value depending on the fuel type and CO_2 emissions. The rate is adjusted in case the vehicle meets only a low emission standard, when it generates high levels of PM, or the CO_2 emission specification is missing.

Fig. 13 Parameters of environmental registration tax based on carbon emissions in Slovenia



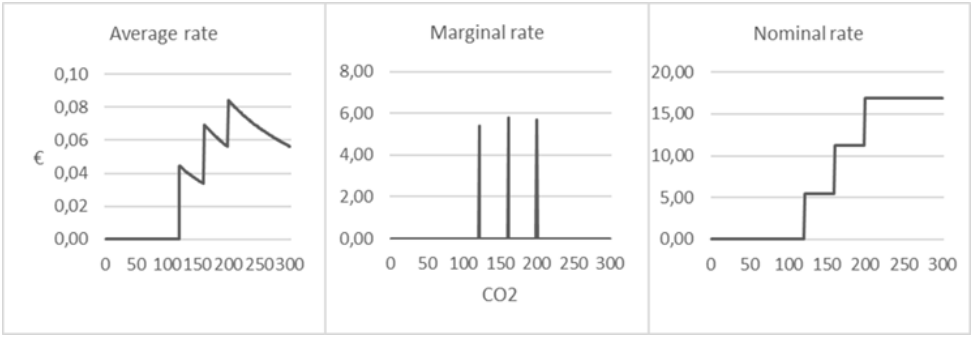
Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) + Authorial computation.

Average rates differentiated by the fuel type sharply drop at the beginning and begin to rise at 111 g CO_2. The last change in the trend is at the level of 267 g CO_2, where the average rate begins to decrease and converge to zero. The existence of grades is apparent even in the average rate shape. The marginal rate is non-zero only when nine values of CO_2 are reached. These are 111, 121, 131, 151, 171, 191, 211, 231 and 251 g CO_2 concordantly for both fuel types. The amounts of non-zero marginal rates differ in relation to fuel types, height of the nine grades and interval length between the grades. The nominal carbon rate is logically graduated, the grades are of different heights, and intervals in between are of different lengths. The shape of the nominal rate does not amount to non-zero values at the beginning and the amount of rate ceases to change from the level of 251 g CO_2.

The tax in Slovenia in term of its graduated nature and progression parameters is unfair and distorting. Significant deviations from the defined optimal shape of the average rate, marginal rate and nominal rate were identified.

The subject of registration tax in Spain is the first registration of new and used passenger cars. The tax base is the selling price of the vehicle or the market price in the case of registration of an older vehicle. The tax rate is graduated and is a percentage of the price depending on CO_2 emissions. The government sets limits which apply as maximum rates for individual regions of Spain.

Fig. 14 Parameters of environmental registration tax based on carbon emissions in Spain



Source: Based on data from ACEA (2019), PwC (2018), David et al. (2018) + Authorial computation.

The average rate of tax on CO_2 emissions is non-zero from 121 g CO_2. It subsequently rises in three grades and then drops until the emissions reach another grade. The average rate decreases and converges to zero beginning with the third grade. The marginal rate identifies three emission values, 121, 161 and 200 g CO_2, where the rate is non-zero. There are slight differences among the rates at these three points. Intervals between the points are basically identical. The shape of the nominal rate includes three increasing grades; the rate remains unchanged until 121 g CO_2 and from 200 g CO_2.

Registration tax in Spain in term of its graduated nature and progression parameters is unfair and distorting. Significant deviations from the defined optimal shape of the average rate, marginal rate and nominal rate were identified.

5 Conclusion

Emissions generated by roadway motor transport contribute to irreversible climate change (Cramer et al. 2001). It is appropriate to address the production of carbon dioxide through tax instruments (Johnson et al. 2013). Although vehicle

registration tax is not an optimal instrument for the inclusion of negative externalities into market prices, the potential externalities can be factored by the tax through setting suitable parameters.

Environmental registration tax based on carbon emissions is a tax that, similarly to other taxes, should not cause further distortions apart from the intentional determination of the market. Further distortions can be avoided through the appropriate design of its parameters. Vehicle registration tax rates based on CO_2 emissions, which are specified in the technical documentation, must be set as either proportional or flexibly progressive.

In their effort to address market failure, EU countries apply vehicle registration tax based on CO_2 emissions in a more or less distorting way. Significant deviations from the defined optimal shape of the average rate, marginal rate and tax or nominal rate were identified in Belgium, France, Greece, Ireland, Malta, Slovenia and Spain. The average tax rates are graduated and often decreasing in certain intervals or along the entire course in these countries. The marginal rate shapes contain peaks, around which the values are zero. The tax or nominal rate show grades with uneven heights and different intervals between them. The amount of carbon tax or its nominal rate is constant from a certain level of CO_2.

Deviations from the optimal shape of the average, marginal or nominal tax rate were observed also in Croatia, Finland, the Netherlands and Portugal. The Croatian system is characterised, in particular, by the graduated nature and local drop in the marginal rate. This results in the locally graduated form of tax. Cyprus applies flexibly progressive average tax rates, which shape is concave. The marginal rate contains grades with different heights and varied intervals in between. In Finland, the starting average rate is very high and the tax is not zero for the zero level of CO_2 emissions. The marginal rate markedly fluctuates; locally increases and decreases again. The Netherlands applies a high average rate where the tax is not zero for the zero level of CO_2 emissions. The marginal rate is graduated and these grades are of different heights and varied intervals in between. In Portugal, the marginal rates are graduated, fluctuating and locally decreasing. The grades differ in their heights and intervals.

The tax system which best approximates the optimal model of CO_2 taxation isapplied in Austria. Both components of the average tax rate are flexibly progressive. However, the progression decreases for the CO_2 based component with growing CO_2 emissions. The marginal rate always includes only one grade, whereas the nominal rate is progressive in the shape of a direct line. Low emission vehicles do not have tax imposed.

In practice it is possible and even appropriate to change certain parameters of the optimal tax model. We can mention an example of the deferred start of non-zero average and marginal rates ensuing from the deferral of non-zero values of the tax. Flexible progression can be also determined as graduated, which will cause a change in the direction of straight lines of the average and marginal progressive rates, resulting in the increase of the progression of the total tax. Nevertheless, the above changes should be based on an intentional need to influence the market that is in an effort to create a distortion that will lead to the pre-set goals, in particular, towards the purchase or sale of more environmentally friendly vehicles in terms of emissions.

The bigger or smaller deviations from the optimum, resulting from the efforts of European Union countries to factor transport externalities through CO_2 based registration tax, have not been caused by intentional distortions of the market. The carbon tax in Austria shows that it is possible to apply a tax which is close to the optimum and which mitigates unintentional distortions of the market caused by graduated or otherwise inappropriately set parameters of the tax. In the European Union it is unthinkable that, for instance, a progressive tax rate would be graduated and thereby cause extensive distortions, which fact has been confirmed by Hagopian (2011). Unfortunately, vehicle registration taxes based onCO2 emissions in EU countries predominantly accord with the definition by Pitelin (2018) in terms of their graduated nature and progression parameters, which means they are unfair and distorting.

References

ACEA, 2019. Acea Tax Guide 2019. Available from: <acea.be/uploads/news_documents/ACEA_Tax_Guide_2019.pdf>. [25 July 2019].

Bethmann, I. et al. 2018. Tax Loss Carrybacks: Investment Stimulus versus Misallocation. Accounting Review 93,101-125.

Blechová, B. 2012. Progresivní nebo „rovná“ daň – ekonomické i politické dilema. Politická ekonomie 60, 649-667.

Buchanan, J. M., Stubblebine, C. W. 1962. Externality. Economica 29, 371–384. Cnossen, S., 2005. Theory and practice of excise taxation: smoking, drinking, gambling, polluting, and driving. Oxford University Press, Oxford.

Cramer, W., et al., 2001. Global response of terrestrial ecosystem structure and function to CO2 and climate change: results from six dynamic global vegetation models. Global Change Biology 7, 357–373.

Cunningham, R., 1960. The problem of social cost. Journal of Law and Economics 3, 1-44.

Council of the European Communities, 1970. Council Directive 70/156/EEC of 6 February 1970 on the approximation of the laws of the Member States relating to the type-approval of motor vehicles and their trailers, Available from: <eur-lex .europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:31970L0156&from=EN>. [13 August 2019].

Council of the European Union, 2015. Council Decision (EU) 2015/1339/EU. Available from: <eur-lex.europa.eu/legal-content/EN/TXT/?qid=154642575 1756&uri=CELEX:32015D1339>. [13 August 2019].

David, P., Montag, J., 2014. Taxing Car-produced Carbon Dioxide Emissions: Matching the Cure to the Disease. Procedia Economics and Finance 12, 111–120.

David, P., 2015. Fair and Effective Environmental Road Tax on Passenger Vehicles. Journal of economics 63, 524–541.

David, P. et al., 2018. Analýza zpoplatnění a zdanění vozidel. Zpráva projektu za rok 2018. Centrum dopravního výzkumu, Ministerstvo dopravy České republiky.

Davies Waldron, CH. et al., 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Energy, Mobile Combustion 2. IPPCC, Hayama.

European Commission, 2013. Commission Decision 2013/162/EU. Available from: <eur-lex.europa.eu/legal-content/EN/TXT/?qid=1546425337416&uri =CELEX:32013D0162>. [15 August 2019].

European Commission, 2011. White Paper. Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. Available from: <eur-lex.europa.eu/legal-content/EN/TXT/?qid=1546425457577 &uri=CELEX:52011DC0144>. [20 August 2019].

European Parliament and Council of the European Union, 2011. Regulation (EU) 691/2011. Available from: <eur-lex.europa.eu/legal-content/EN/TXT/?qid= 1546425554791&uri=CELEX:32011R0691>. [18 August 2019].

Fatica, S., Prammer, D., 2018. Housing and the Tax System: How Large Are the Distortions in the Euro Area? Fiscal Studies 39, 299-342.

Federal Ministry of Finance – Republic of Austria, 2019. Normverbrauchsabgabe (NoVA), Available from: <bmf.gv.at/steuern/fahrzeuge/normverbrauchsabgabe. html>. [2 November 2019].

Finnish Tax Administration – Vero Skatt, 2019. Verotaulukko. Available from: <https://www.vero.fi/globalassets/henkiloasiakkaat/autoverotus/verotaulukko-1a_1365_2018.pdf>.[4 November 2019].

Finnish Tax Administration – Vero Skatt, 2019a. Ajoneuvojen veroprosentit. Available from: <vero.fi/henkiloasiakkaat/auto/autoverotus/autoveron_maara/ ajoneuvojen-veroprosentit/#henkiloauto>. [4 November 2019].

Fullerton, D., Metcalf, G. E., 1997. Environmental taxes and the double-dividend hypothesis: Did you really expect something for nothing? NBER Working Paper 6199. National Bureau of Economic Research. Available from: <ase.tufts.edu/economics/papers/9706.pdf >. [20 August 2019].

Gandhi, V. P., Cuervo, J., 1998. Carbon Taxes-Their Macroeconomic Effects and Prospects for Global Adoption – a Survey of the Literature. IMF Working Paper WP/98/73. International Monetary Fund. Available from: <imf.org/en/Publications /WP/Issues/2016/12/30/Carbon-Taxes-Their-Macroeconomic-Effects-and-Prospects-for-Global-Adoption-A-Survey-of-the-2601>. [21 August 2019].

Goulder, L. H., 1995. Environmental taxation and the double dividend: a reader's guide. International tax and public finance 2, 157–183.

Goulder, L. H., 2000. Economic Impacts of Environmental Policies. NBER Reporter. National Bureau of Economic Research. Available from: <nber.org/reporter/spring00/goulder.html>. [16 August 2019].

Hagopian, K., 2011. The inequity of the progressive income tax. Policy Review 166, 3–17.

Hilber, C. A. L., Lyytikaeinen, T., 2017. Transfer taxes and household mobility: Distortion on the housing or labor market? Journal of Urban Economics 101, 57–73.

Johnson, P. et al., 2013. Fuel for Thought: The what, why and how of motoring taxation. Institute for Fiscal Studies for the RAC Foundation, London.

Kampas, A., Horan, R., 2016. Second-best pollution taxes: revisited and revised. Environmental Economics and Policy Studies 18, 577-597.

Landoni, M., 2018. Tax distortions and bond issue pricing. Journal of Financial Economics 129, 382-393.

Leicester, A., 2005. Fuel taxation. Briefing Note No. 55. The Institute for Fiscal Studies. Available from: <ifs.org.uk/bns/bn55.pdf>. [1 December 2019].

Manabe, S., Wetherald, R. T., 1980. Distribution of Climate Change Resulting from an Increase in CO2 Content of the Atmosphere. Journal of the Atmospheric Sciences 37, 99–118.

Meade, J. E., 1952. External economies and diseconomies in a competitive situation. The Economic Journal 62, 54–67.

Nordhaus, W. D., 2006. The "Stern review" on the economics of climate change. NBER Working Paper 12741. National bureau of economic research. Available from: <nber.org/papers/w12741.pdf>. [12 October 2019].

Ntziachristos, L., Samaras, Z., 2016. EMEP/EEA air pollutant emission inventory guidebook 2018 (Part B – 1.A.3.b. Road transport, update 2018), EEA, Luxenbourg.

Organisation for Economic Co-operation and development, 2011. Environmental Taxation. OECD Publications. Available from: <oecd.org/env/tools-evaluation/48164926.pdf>. [15 August 2019].

Parry, I. W., et al., 2007. Automobile externalities and policies. Journal of Economics 60, 373-399.

Parry, I. W., et al., 2012. Environmental tax reform: principles from theory and practice. Annual Review of Resource Economics 4, 101–125. Available from: <doi.org/10.1146/annurev-resource-110811-114509>. [15 August 2019].

Pastor, J., Post, W. M., 1988. Response of Northern Forests to CO2-Induced Climate Change. Nature 334, 55–58.

Pelikán, L. et al., 2018. Zavedení programu COPERT 5 pro výpočet emisí ze silniční dopravy v České republice: Závěrečná zpráva. Centrum dopravního výzkumu, Brno.

Pigou, A. C., 1920. The Economics of Welfare. McMillan & Co., London.

Pitelin, A. K., 2018. On the Fair Scale of Progressive Taxation. Economics and Mathematical Methods 54, 29-40.

PricewaterhouseCoopers, 2018. 2018 Global Automotive Tax Guide, Available from: <pwc.de/de/automobilindustrie/2018-pwc-global-automotive-tax-guide.pdf >. [25 July 2019].

Proost, S. et al., 2009. Will a radical transport pricing reform jeopardize the ambitious EU cli-mate change objectives? Energy Policy 37, 3863-3871.

Sallee, J. M., 2011. The taxation of fuel economy. Tax Policy and the Economy 25, 1-37.

Sandmo, A., 1975. Optimal taxation in the presence of externalities. The Swedish Journal of Economics 77, 86–98.

Santos, G. et al., 2010. Externalities and economic policies in road transport. Research in Transportation Economics 28, 2–45.

Sergeant, N. et al., 2008. The influence of potential policy measures on the eco-efficiency of personal vehicle mobility in Brussels. WIT Transactions on the Built Environment 101, 291-300.

Smith, A., 1776. The Wealth of Nations. Oxford University Press, London.

Stern, N. et al., 2006. Stern Review: The economics of climate change. Cambridge University Press, Cambridge.

United Nations, 1992. United Nations Framework Convention on Climate Change. Available from: <mzp.cz/C1257458002F0DC7/cz/ramcova_umluva_osn_zmena_klimatu/$FILE/OMV-anglicky_umluva-20081120.pdf>. [25 August 2019].

United Nations, 1997. Kyoto Protocol to the United Nations Framework Convention on Climate Change. Available from: <mzp.cz/C1257458002F0DC7/cz/kjotsky_protokol/$FILE/OMV-anglicky_protokol-20081120.pdf>. [25 August 2019].

Ye, J. L. et al., 2018. The Heterogenous Tax Burden: Evidence from Firm-Level Data in China. Singapore Economy Review 63, 1003–1035.