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The Relationship between Road Tax Rate Reduction Depending on Vehicle Age and Emission Parameters of Taxed Vehicle Categories in the Czech Republic¹

Petr DAVID*

Abstract

Due to the processing of unique data concerning the vehicle fleet of the Czech Republic and the national emission inventory, this paper examines the relevance of the benefits available for newer vehicles by means of the Czech road tax against the principle of internalization of road transport externalities. A serious finding is that the highest tax benefits are available for vehicles that generate the largest amount of CO₂ and NO_x emissions. The findings should serve as support for the adjustment of road tax reductions in the Czech Republic. Based on the similarities between the Czech and Slovak fleets and relevant legislation, the preferential treatment of taxation of newer vehicles applied in Slovakia can be assessed through a similar method. On a general level, the examination proved that the input data are suitable for the application of a fiscal instrument that accounts for emissions in road transport.

Keywords: road tax, tax rate reduction, emissions, environmental tax

JEL Classification: H21, H23

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1. Introduction

Road transport accounts for the generation of significant negative externalities. The production of emissions by motor vehicles is determined mainly by the state and parameters of the fleet.

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The Czech Republic (CR) and Slovakia are exceptions among the European Union (EU) in that they levy taxes only on the operation of motor vehicles used for business purposes (ACEA, 2020; PwC, 2019). In the CR, this is stipulated by Act No. 16/1993 (CNR, 2020) and in Slovakia by Act No. 361/2014 (NRSR, 2020). These two countries reflect the purpose of the vehicle in their tax rates, but not the vehicle's operation or the generation of externalities. Both countries adjust annual road tax rates depending on the number of months since the date of first registration.

Table 1

Reduction of Tax Rates in the CR and Slovakia

Vehicle age (months)	0 – 36	37 – 72	73 – 108	109 – 144	145 – 156	157 <
Rate reduction in the CR (%)	-48	-40	-25	0	0	0
Rate reduction/increase in Slovakia (%)	-25	-20	-15	0	+10	+20

Source: ČNR (2020), NRSR (2020), author.

The tax rate adjustments shown in Table 1 may place emphasis on faster renewal of the fleet. However, looking at the average age of the CR's fleet in comparison with other EU countries, it must be noted that this instrument is not sufficient for efficient fleet renewal. The average age of vehicles in the CR in 2018 was 14.8 years; in Slovakia it was 13.9. These are the fifth and seventh oldest fleets in the EU, respectively (ACEA, 2019). The CR had the sixth lowest renewal rate in 2017, whereas Slovakia was better in this respect. There are 17 EU countries that show a lower renewal rate, but there has been an undesirable 2.3% reduction in this rate since 2008 (Eurostat, 2019). The European Environment Agency data (EEA, 2020) and Friedrich's (2011) maps show that in terms of air pollutant concentrations, the CR and Slovakia perform poorly compared to other EU countries.

The World Health Organization's data (WHO, 2018) suggests that there are many thousands of deaths attributable to ambient air pollution in the CR and Slovakia. Air pollution is a negative externality of road transport (Fiorito, 2017; Mostert, Caris and Limbourg, 2017) that may be included in the market mechanism through intervention by the public sector in the form of a corrective tax or other fiscal instruments. Commonly applied taxes include registration and operation. Further fiscal instruments include registration fees, a bonus-malus system upon the acquisition of a vehicle, various forms of scrappage schemes, tolls and fees based on time. Besides a road tax, the CR also applies registration fees depending on the EURO standard, fees based on time for vehicles of up to 3.5 t and tolls for vehicles over 3.5 t that consider the number of axles, vehicle weight, emission standard, type of road and time of day. Slovakia charges a motor tax,

a registration fee scaled to engine capacity and age of the vehicle, time fees for vehicles up to 3.5 t along with certain trailers and tolls for vehicles over 3.5 t that consider the vehicle type, weight, number of axles and emission standard.

For the purposes of designing and applying effective instruments for the inclusion of externalities in road transport emissions, the emissions must be described and measured as accurately as possible. The tax policy practice may be based either on the nominal values of emissions per unit of distance traveled or emissions according to the data in the technical documentation of the vehicle; the design of the tax policy may consider the real data on vehicles in operation and the distance they travel and thus on the dynamic characteristics of total emissions generated.

Based on unique data concerning the Czech fleet, this article first aims to compare the unit characteristics of vehicle and fleet emissions as well as the total fleet emissions while factoring in the distance traveled; it will also ascertain whether the shares of individual vehicle categories in the aggregate unit, average and total emissions will differ. Subsequently, it will be possible to ascertain whether, in view of the direct proportion principle that factors externalities, the differentiation of annual tax rates based on the vehicle's age is adequate. The stated evidence will apply to the CR. It will also be possible to formulate general implications for Slovakia based on the results identified in the CR, similarities of the main parameters of the fleets and similar taxation principles. At the same time, it will be possible to formulate universally applicable statements as to whether the results for vehicles with problematic emissions differ within their respective characteristics and whether it is efficient to use data regarding distance traveled and frequencies of occurrence within the framework of the fleet to formulate tax policy.

1.1 Fiscal Instruments for the Internalization of Road Transport Externalities

Market entities tend to behave rationally rather than environmentally; therefore, the environmental issue must be transformed into the rational minimization of costs. This can be done through fiscal instruments applied by the public sector, thus determining the environmental behavior of business entities. Such instruments in the context of the environmental impact of road transport *inter alia* include fuel tax, carbon tax, mileage tax, annual road tax, motor vehicle tax and registration tax.

The annual road tax, which should be considered an environmental tax, is collected as a means to reduce emissions by vehicles that use fossil fuel (Carling et al., 2017; Dong et al., 2017; Fiorito, 2017; Marriot and Mortimore, 2017; Rasool,

Zaidi and Zafar, 2019; Zhou et al., 2018). The following authors see advantages of this tax: according to Pearce (1991), it corrects distortions, Barbieri (2015) sees a positive correlation between environmental taxes and green automotive patent activity, Solaymani and Kari (2013) and Scrimgeour, Oxley and Fatai (2005) appreciate a relatively low impact on value-added tax and investment, according to Pui and Othman (2017) it generally contributes to better quality of the environment and Kim Han and Moon (2011) consider the tax cost-effective.

The disadvantages of the tax are seen by Bjertnaes (2019) in the manufacturers' tendency to cheat in measuring and declaring this indicator, by David (2012; 2015) in substituting citizens' education and information with mere financial pressure, by Carling et al. (2017) in the reduction of CO₂ emissions due to a slower transition to e-tailing, by Alberini et al. (2018) in the reduction of emission benefits by postponing the purchase of a vehicle, and by Scrimgeour, Oxley and Fatai (2005) in the decrease of the gross domestic product and household consumption and welfare. Neither Klier and Linn (2015) nor Alberini and Bareit (2017) support this tax.

However, Lu, Tong and Liu (2010) suggest that the negative impact of the tax can be mitigated by complementary policies while maintaining a relatively large reduction in carbon emissions.

As clearly formulated by Santos (2017), taxes and subsidies are necessary for the faster decarbonization of transport. Liu and Santos (2015), however, admit that tax instruments and subsidies by themselves will not suffice for the achievement of the environmental goals laid out in the Paris Agreement (United Nations, 2015); this is also supported by Achtnicht, Buhler and Hermeling (2012). Parry et al. (2014) maintain that equilibrium must be reached between the tax benefits for the environment and economic costs. The basic premise remains the same: the existing fiscal instruments must be revised, their optimal setting discussed and realistic partial steps promoted. Detailed knowledge of concrete emission parameters and the characteristics of existing road transport is necessary to reach these goals.

1.2. Quantification of Transport Emissions

Transport emissions can be quantified by means of the traffic air quality index (Bagiński, 2015), vehicle specific power methodology, Corinair methodology (Coelho et al., 2014), the road network dispersion model Contaminants in the Air from a Road – Finnish Meteorological Institute (CAR-FMI) (Kukkonen et al., 2001) or the Danish operational street pollution model with the support of emission factors from the Copert 4 model (Berkowicz, 2000; Ketzel et al., 2012). We can also use the Norwegian emission model (Sandmo, 2016), which works with

partial models from the road transportation sector to determine emission factors by means of mileage and emissions/km data. The following models are also often cited: microscale dispersion model (OMG) (Kono and Ito, 1990), Roadway (Eskridge and Catalano, 1987) or the travel demand model (TDM), which factors in the distance traveled (Wang et al., 2009).

An essential tool for the quantification of emissions at the national level is the Copert model, a software tool for the calculation of air pollutants and greenhouse gas emissions from road transport on a regional or national scale. Copert is a technologically advanced and transparent model that includes all the main pollutants reported by many European countries in their official emission data (Emisia, 2020). The Copert model is used by Lozhkina and Lozhkin (2015), who aptly describe the shortcomings of its application, which may arise when applied to real data. In spite of these limitations, the authors consider Copert more fitting than the alternatives since the fleet and activity data are available and carefully processed. According to Pelikán and Brich (2018), Copert enables consistent, transparent and comparable calculation that corresponds to all requirements of international treaties and European legal regulations. The EEA (2019) mentions the Copert program as a model surpassing the existing methods of addressing the transportation sector issues.

2. Data and Methodology

2.1. Source Data Identification

In order to meet the preset goals, the data from different sources must be used to identify the characteristics of the Czech fleet. Such unique data comes from the CR's Register of Motor Vehicles (RMV) (TRC, 2019), vehicle testing stations (VTS) (TRC, 2019a) and the Copert national emission inventory for the CR (TRC, 2019b) provided by the Transport Research Centre (TRC).

Table 2 shows the data sources and related variables necessary to meet the research goals.

Table 2

Identification of Data Sources for Variables Used

Variable	Owner	Category	Age	Engine capacity	Weight
Source	RMV	RMV	RMV	RMV	RMV
Variable	Number of axles	Distance traveled	NO _x emissions	PM _{2.5} emissions	CO ₂ emissions
Source	RMV	VTS	Copert	Copert	Copert

Source: Author.

2.2. Description and Justification of Source Data

The source data includes information from the 2018 RMV (TRC, 2019) and distances traveled as recorded by Czech VTS (TRC, 2019a) over a period of four years; this data can be considered complete. The mileage data in the given year recorded by VTS has been used to determine average distances traveled in the individual categories of passenger cars (PC), light commercial vehicles (LCV), heavy goods vehicles (HGV), and semi-tractors (ST). The 2018 extract from VTS can be considered a source of complete and unchangeable activity data (Pelikán, Brich and Špička, 2017). The data from technical inspections amounts to 70%, which is sufficient to calculate the average distances traveled by vehicles in their respective categories.

Pollutants are categorized in Copert depending on the sophistication of the methodology applied to determine their emission factors (Pelikán and Brich 2018). Important emission factors that have been thoroughly examined by scientists and whose methodology of calculation is well developed are mainly CO₂, NO_x and PM_{2.5}, according to the EEA (2019) and the Intergovernmental Panel on Climate Change (IPCC, 2006). The Copert input data (TRC, 2019b) is the result of the practical application of the Copert 5 program to emission inventories in the conditions of the CR according to Pelikán, Brich and Ličbinský (2018), Ntziachristos and Samaras (2016) and Davies Waldron (2006) for the purpose of identification of CO₂, NO_x and PM_{2.5} values.

2.3. Research Procedure

The calculations of the respective emission factor values are based on real data from the RMV in 2018. In this study, we filter the larger part of the RMV data, which represents 85% of the Czech fleet and covers PCs, LCVs, HGVs and STs. STs are vehicles designed for long-distance transport of large volumes of goods or loads placed on a semi-trailer, not agricultural tractors, which are not primarily intended for operation on roads. The study does not work with motorcycles (M), whose share in the fleet is 15%, or buses (B), which have less than a 1% share in the CR's fleet.

The VTS and RMV data are interconnected by unique identifiers of the vehicles' categories (PC, LCV, HGV, and ST). Emissions are calculated from distances traveled per year by 373 concrete groups of vehicles. The vehicles are included in a particular group according to their technical properties as registered in the RMV. The data set classifying the fleet's vehicles into specific groups corresponding to the national emission inventory output has been created through the above procedure. Vehicle age is identified in a similar manner (i.e., using the

base data from the RMV and creating four age groups: 0 – 36 months, 37 – 72 months, 73 – 108 months, and 109 months or more in accordance with the parameters of reduction of annual road tax rates in the CR under Section 6(6) of Act No. 16/1993 Coll., on Road Tax.

We also identify the types of vehicle owners. Further processing of the data results in the creation of aggregated statistics that enable us to identify Czech fleet characteristics in terms of distributing frequencies of occurrence, distance traveled, the proportion of CO₂, NO_x and PM_{2.5} emissions (depending on vehicle categories), the selected distance parameter and age of the commercial vehicle.

The main descriptive characteristics of the vehicle categories by age groups are the frequency of occurrence, average distance traveled and total distance traveled. The characteristics of frequency of occurrence and distance traveled are further converted into ratio indexes so that they better demonstrate the shares of categories and age groups in the identified values.

Emission characteristics are unit emissions, average emissions and total emissions. Unit emissions are the emissions produced by the defined vehicle while traveling a distance of 1 km. Average emissions take into account the distance traveled by a given group of vehicles defined by the identification data, technical properties and age of the vehicle. If we determine an average distance traveled by each group of vehicles, we can calculate emissions of the defined vehicle, factoring the distance that corresponds to the average distance traveled by the given group. The total emissions are then defined as a product of average emissions and frequency of occurrence of vehicles included in the given group according to the identification characteristics, technical properties and age of the vehicle. The three aforementioned emission characteristics are then converted into ratio indexes in order to easily compare the shares of individual categories and age groups in the production of emissions.

3. Results

The 2018 RMV data includes all 6.39 million vehicles in the CR, of which more than 99% were processed and sorted according to vehicle category and type of owner. There are 1.14 million (18%) commercial vehicles, 4.83 million (76%) private vehicles and 0.38 million (6%) vehicles owned by foreign naturals or legal persons.

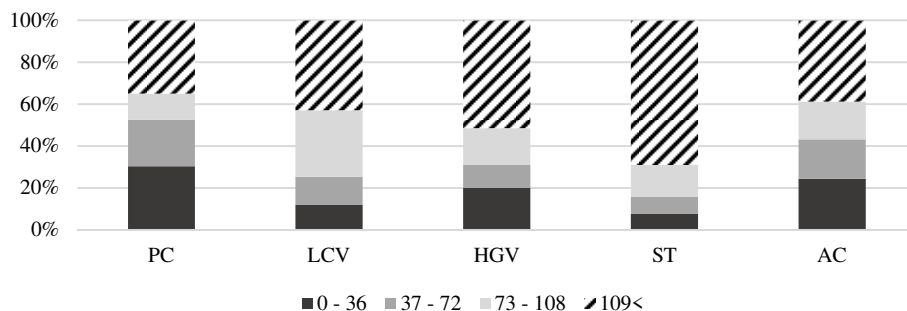
Altogether, 0.93 million commercial vehicles were clearly identified in terms of age, which resulted in an additional data loss of 19%. It may be assumed that it is the data on older vehicles that is missing from the RMV; however, this cannot be proved.

Therefore, we will not supplement the missing data, since this would increase uncertainty concerning the relevance of the result and the possible range of deviations from the real state. However, we will bear in mind the loss of around 20% of the data on commercial fleets when interpreting the results. The suggested procedure is also supported by the fact that the outcome of the emission quantification shall be percentages rather than absolute values.

Another loss of data is attributed to the impossibility of identifying the distance traveled by any vehicle in a given category due to the imperfection of the data from the VTS. Therefore, missing information cannot be replaced with information regarding the average distance traveled by the other vehicles in the given category. This reduces the fleet data set included in the calculations by 3%.

The final 0.89 million vehicles included in the research are further used for the identification of the main statistics of the commercial fleet in relation to the age of the vehicles. The frequencies of occurrence of the individual categories are as follows: 64% are PCs, 27% are LCVs, 8% are HGVs, and only 1% are ST vehicles.

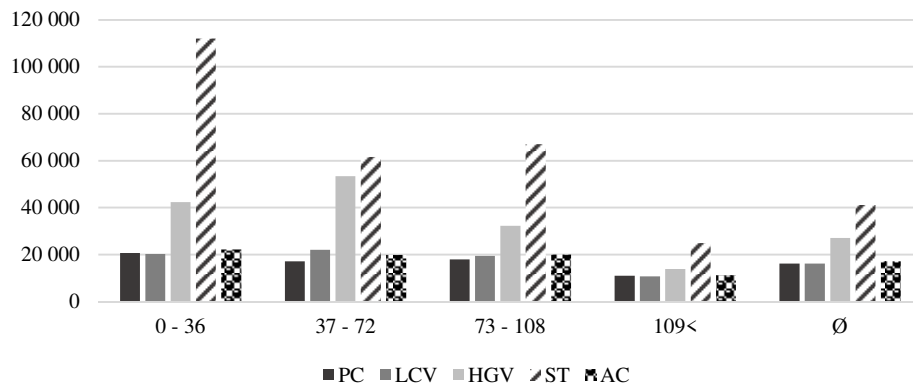
Figure 1
Percentage of Frequency of Occurrence in Age Groups (months)



Source: Author, based on TRC (2019; 2019a; 2019b).

All categories are clearly dominated by vehicles older than 108 months, whose total share is 39%, as shown in Figure 1. This group, which is the most disadvantaged in terms of taxes, includes the largest share of ST vehicles; the smallest share is represented by PCs. The largest share in the age group of 73 – 108 months is held by LCVs. PCs account for the largest shares in the categories of 0 – 36 and 37 – 72 months, with an aggregate share of 53%. It can be said that PCs significantly change the ratio of old to new vehicles in favor of the new ones within the aggregated category (AC) comprised of vehicles from all four categories. The proportion of vehicles older than 72 months is 57% due to the substantial share of older vehicles in the LCV, HGV and ST categories.

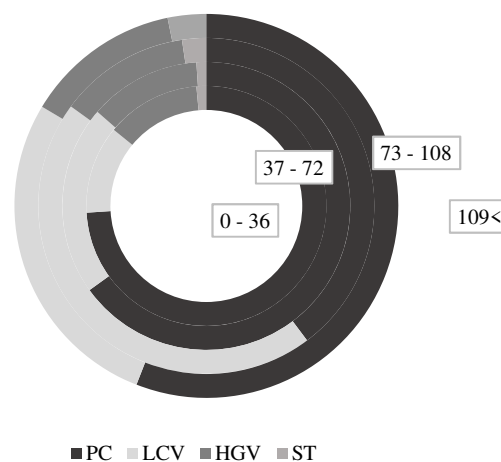
Figure 2
Average Distances Traveled by Vehicle Categories in Age Groups (km)



Source: Author, based on TRC (2019; 2019a; 2019b).

Figure 2 illustrates the fact that the longest distances across all age groups were traveled by ST vehicles, with a total average value of 41 thousand km per year. The highest mileage occurs with ST vehicles in the “newest” age group (up to 36 months). The above-mentioned facts are a testament to the widespread utilization of these vehicles. The shortest average distance (16 thousand km) was traveled by PCs and LCVs. It is apparent that the shortest average distances were traveled by the oldest vehicles. The most important categories in terms of direct proportion between emission levels and distances traveled are vehicles in the ST category and those in the age groups with tax benefits (up to 108 months).

Figure 3
Share of Total Distances Traveled in Age Groups



Source: Author, based on TRC (2019; 2019a; 2019b).

If we recalculate the average distances traveled in relation to the frequencies of occurrence, we obtain the absolute distances in the respective vehicle categories and age groups, as depicted in Figure 3. The chart is dominated by the PC category, particularly PCs newer than 36 months, which receive the most preferential tax treatment; the absolute number is 3.64 billion km traveled. The LCV age group of 37 – 72 months shows the longest absolute distance of 1.48 billion km. HGVs only report a longer absolute distance than LCVs in the group of up to 36 months. The shortest absolute distance traveled was recorded in the ST category, although as mentioned above, these vehicles have the highest average figures. This is attributed to a smaller frequency of occurrence that does not exceed 7 thousand PCs in comparison with the other vehicle categories.

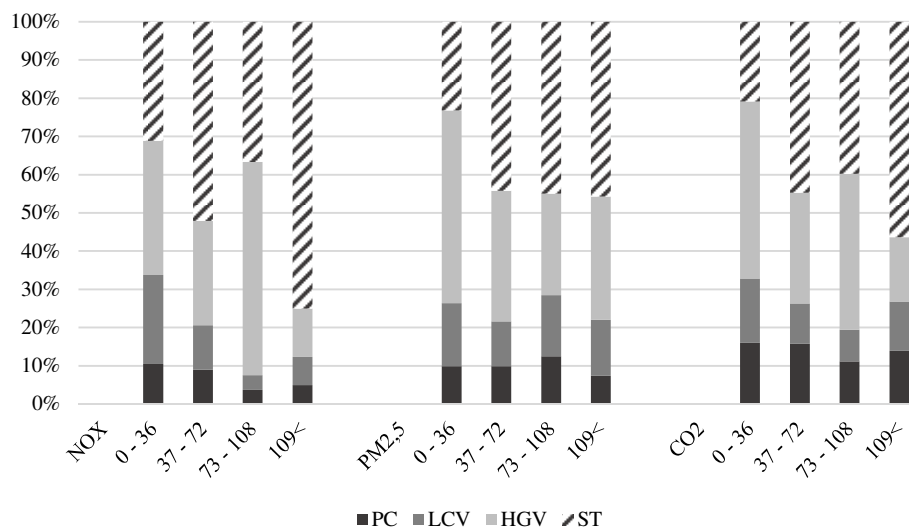
Based on the data from the RMV, it may be said that in terms of pollutant emissions, vehicles older than 108 months are considered risky with regard to the distribution of total frequencies of occurrence, the vehicles in the ST category are considered risky with regard to average distances traveled in all age groups and PCs are considered risky with regard to the total sum of distances traveled by vehicles in all age groups with the exception of the group from 73 – 108 months, where the longest total distance was traveled by LCVs. In order to clearly determine the emissions of these potentially risky groups, we must not only include quantitative data from the RMV and VTS in the statistics, but also match each vehicle with concrete emission parameters in accordance with the Copert national emission inventory.

A graph of the percentages of NO_x, PM_{2.5} and CO₂ unit emissions in the relative expression is provided in Figure 4. The largest percentage of NO_x emissions is attributed to STs and HGVs, which account for 86% of emissions without differentiating among age groups. It is clear that STs and HGVs over 72 months old produce larger amounts of NO_x emissions than newer vehicles. The largest share of NO_x unit emissions is reported in STs older than 108 months, the most disadvantaged group in terms of taxes, where the absolute value approaches 8 g/km/vehicle. The share of unit emissions of PM_{2.5} in HGV and ST vehicles without differentiating among age groups is 78%. The result is not much different if the age groups are specified. However, a larger share of PM_{2.5} emissions in HGVs in the age group of up to 36 months, which receives the most preferential tax treatment, and a smaller share of PM_{2.5} emissions in STs aged 36 months or less were identified. The maximum absolute value of PM_{2.5} is 0.27 g/km/vehicle in the ST category aged over 108 months. Unit emissions of CO₂ are again dominated by HGVs and STs, whereas the share of the ST category grows with the age of the vehicle to as much as 56%, with an absolute value of 854 g/km/vehicle. On the other hand, in new vehicles of 36 months or less, the prevailing category

is HGV, with its share of unit emissions reaching 46%. The shares of the PC and LCV categories in unit emissions are less significant than HGV and ST; there is not much difference among age groups. Only the increase in shares in NO_x unit emissions of new PCs and LCVs, which get the most tax benefits, is noticeable. Of course, this is not attributed to poor emission parameters of new PCs and LCVs, but rather to the dynamic improvement of the emission parameters of the other categories, particularly ST vehicles. However, STs are clearly the worst type of vehicles in terms of unit emissions without differentiating among age groups. This is particularly true of NO_x, but also CO₂ and PM_{2.5} emissions, although in the last case, the HGV category is right behind.

Figure 4

Percentage of Production of Unit Emissions (per vehicle and km traveled) in Age Groups



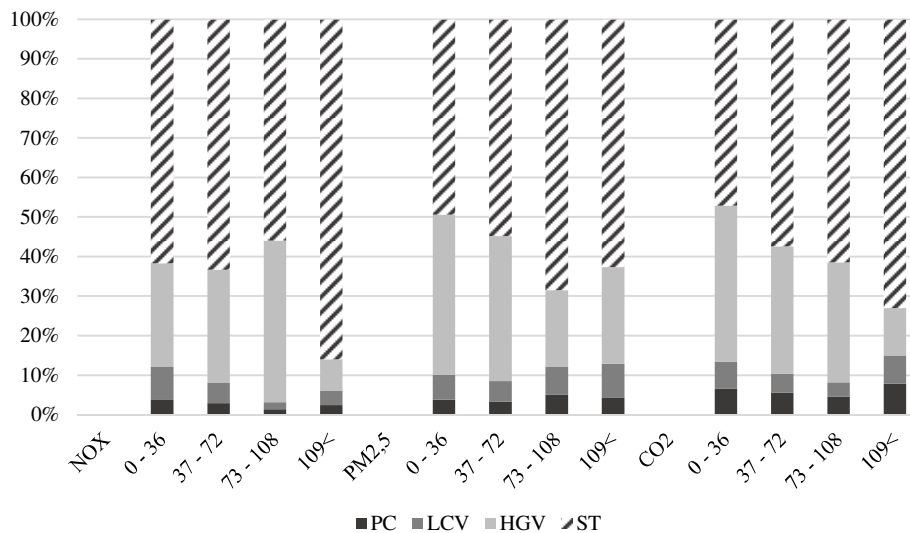
Source: Author, based on TRC (2019; 2019a; 2019b).

Figure 5 shows the inclusion of average distances traveled in the calculation of unit emissions. Through this process, we obtain the emissions per vehicle in the given category and age group while factoring the average distances traveled by vehicles of that category and age group. We can see a clear increase in the shares of the ST category in average emissions due to the high average annual mileage of the vehicles. The ST category also reports the highest absolute amount of NO_x emissions, reaching 245 kg/vehicle/year. The share of NO_x produced by ST vehicles in the age group over 108 months, which is disadvantaged in terms of taxes, is as high as 85%. The share of the ST category also dominates in the average emissions of PM_{2.5} and CO₂, where this share increases (up to

72%) with the vehicle's age. The absolute maximum of 8 kg/vehicle/year of $PM_{2.5}$ is reported in the ST category of 37 – 72 months, which receives tax benefits. The highest CO_2 average emissions are found in the ST category of 73 – 108 months, with a value of 42 t/vehicle/year. The shares of the average emissions of the PC and LCV categories are relatively small for all types of pollutants; there is no pronounced tendency regarding the individual age groups. The age of the vehicles only affects the shares of average emissions of HGVs and STs; the share of ST vehicles grows with increasing age, while the same share declines in the HGV category.

Figure 5

Percentage of Production of Average Emissions (per vehicle and average distance traveled by categories) **in Age Groups**



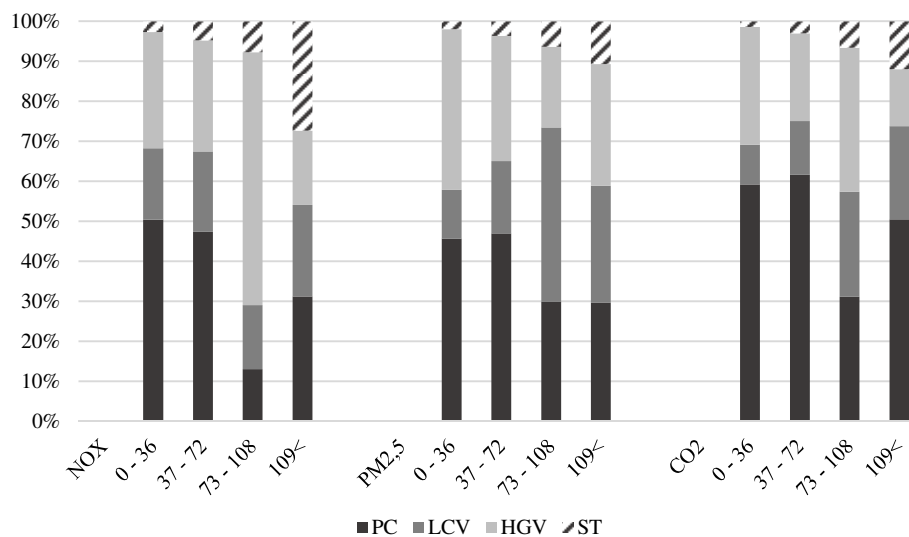
Source: Author, based on TRC (2019; 2019a; 2019b).

Finally, we will include the frequencies of occurrence of the respective vehicle categories in the calculation of emission parameters for the Czech fleet. Figure 6 shows the percentage of total emissions of NO_x , $PM_{2.5}$ and CO_2 produced by each category sub-divided by age group. The percentage of NO_x emissions is largely determined by the affiliation with a particular age group. The largest share of NO_x emissions is produced by HGVs in the age group from 73 – 108 months (which get tax benefits). Its share is 63% and the absolute value exceeds 2 kt NO_x . The share of PCs is significant, reaching 51% in the category of up to 36 months, which receives the most preferential tax treatment. The percentage is a little lower in the age group of 37 – 72 months. The share of ST vehicles in the total NO_x emissions grows as they age. Vehicles in the PC, LCV and HGV categories have

the largest share in the total PM_{2.5} emissions. The share of ST vehicles in the total emissions is small and shows a decrease with newer vehicles. A 47% share, the largest in the total emissions of individual age groups, is attributed to PCs in the age group of 37 – 72 months, which receive substantial tax benefits. The absolute maximum is 98 t of PM_{2.5} in HGVs over 108 months old, closely followed by PCs over 108 months old. As for the total production of CO₂, PCs from 37 – 72 months old are clearly dominant in terms of contribution to the total CO₂ production, with a maximum share of 62%. The absolute maximum of 755 kt CO₂ has been identified in the PC age group of up to 36 months, which receives the most preferential tax treatment. The share of ST vehicles in the total emissions of CO₂ is small and decreases with newer vehicles.

Figure 6

Percentage of Total Emissions Produced By Vehicles in Age Groups



Source: Author, based on TRC (2019; 2019a; 2019b).

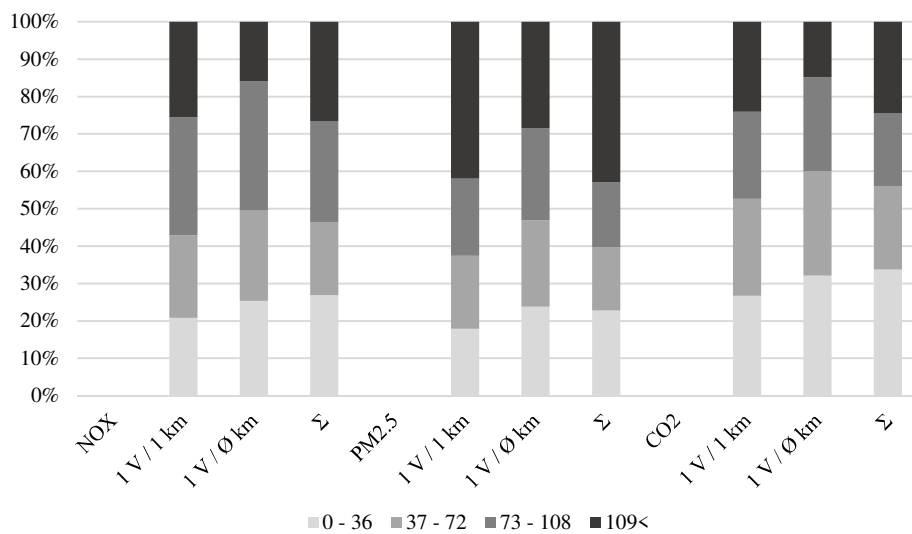
Let us now disregard the vehicle categories to focus on the characteristics of the shares in emission production by the respective age groups. In Figure 7 we can see a summary of shares of the age groups by unit (1V/1 km), average (1V/Ø km) and total (Σ) emissions of NO_x, PM_{2.5} and CO₂.

Vehicles aged 73 – 108 months seem problematic in terms of unit and average emissions of NO_x. However, if we express the total emissions without taking the vehicle categories into account, the shares of the individual age groups become more balanced and the reduction of road tax rates seems inadequate. The characteristics of PM_{2.5} emissions show that the largest shares of unit, average and total emissions are produced by vehicles older than 108 months; a tax rate

reduction for newer vehicles is justifiable in this respect. The characteristics of CO₂ emissions suggest that the shares of unit emissions are balanced across the age groups. Average emissions are higher in newer vehicles because they travel longer distances. This effect is also accentuated by the inclusion of frequency of occurrence: there are more newer than older vehicles driving along Czech roads. Any road tax rate reduction in this case is not considered expedient.

Figure 7

Comparison of Shares in Emission Production by Vehicles across Age Groups



Source: Author, based on TRC (2019; 2019a; 2019b).

Lastly, we will present the absolute values of emission levels (unit – 1V/1 km, average – 1V/Ø km and total – Σ) in the respective age groups without taking the vehicle categories into account. Thus, it will be possible to compare the characteristics of emission production focusing only on age groups.

Figure 8 works with absolute values of unit, average and total emissions of NO_x, PM_{2.5} and CO₂; at the same time, it indicates the seriousness of the given value within its relevant characteristic through the color shading of the table's cells. All three characteristics of NO_x emissions identify the groups of vehicles from 73 – 108 months old (i.e., vehicles that receive tax benefits both in the CR and Slovakia) as the most important. The assessment of PM_{2.5} and CO₂ emissions is similarly consistent, whereas the critical group producing PM_{2.5} is vehicles older than 108 months. The most problematic group in terms of CO₂ is vehicles newer than 36 months, which receive the most preferential tax treatment. In the absolute expression, commercial vehicles in the CR produce approximately 13 kt NO_x, PM_{2.5} approaching 1 kt, and almost 4 mt CO₂.

Figure 8

Identification of Problematic Age Groups According to Characteristics of Emission Production

Age/NO _x	1 V/1 km (g)	1 V/Ø km (kg)	Σ (kt)
0 – 36	0.73	16.32	3.58
37 – 72	0.78	15.53	2.60
73 – 108	1.11	22.26	3.60
109<	0.90	10.27	3.54
Ø	0.86	14.91	13.33
Age/PM _{2.5}	1 V/1 km (g)	1 V/Ø km (kg)	Σ (kt)
0 – 36	0.03	0.78	0.17
37 – 72	0.04	0.76	0.13
73 – 108	0.04	0.81	0.13
109<	0.08	0.93	0.32
Ø	0.05	0.84	0.75
Age/CO ₂	1 V/1 km (g)	1 V/Ø km (kg)	Σ (kt)
0 – 36	259.13	5,801.64	1,272.87
37 – 72	251.23	5,027.88	841.89
73 – 108	225.51	4,541.66	735.56
109<	233.08	2,671.47	921.56
Ø	243.68	4,220.22	3,771.89

Source: Author, based on TRC (2019; 2019a; 2019b).

4. Discussion

The results of the research show that in terms of pollutant emissions, vehicles older than 108 months are considered risky with regard to the distribution of total frequencies of occurrence, vehicles in the ST category are considered risky with regard to average distances traveled in all age groups and PCs are considered risky with regard to the total sum of distances traveled by the vehicles in all age groups. This finding testifies to a large variety of results in the case of applying different variables during the process of identifying the potentially risky segments of the fleet. The methodological procedures and applied data similarly lead to largely varying conclusions and recommendations; for examples refer to Kim, Han and Moon (2011), Marriot and Mortimore (2017) and Rasool, Zaidi and Zafar (2019) versus Alberini et al. (2018), Klier and Linn (2015) and Scrimgeour, Oxley and Fatai (2005).

After including the results of emission inventories used in accordance with Ketznel et al. (2012), Lozhkina and Lozhkin (2015), Pelikán and Brich (2018) and the EEA (2019), the following segments of the commercial fleet are considered problematic in view of emission production: the HGV and ST categories in all age groups with regard to NO_x unit emissions and the HGV and ST categories (except for STs of up to 36 months) with regard to unit emissions of PM_{2.5} and

CO₂. The absolute values of the unit characteristics suggest that the worst emission levels are attributed to the oldest vehicles in the ST category. The characteristics of the average emission levels of vehicle categories in all age groups support the results reached through the unit characteristics and identify the ST vehicles, particularly the old ones, as the worst concerning all the examined emission factors. However, after the inclusion of frequency of occurrence, the characteristics of the total emissions of all vehicle categories with the inclusion of distance traveled through Sandmo's (2016) procedure across the age groups have identified different types of commercial vehicles as problematic in terms of emissions: PCs of up to 72 months for all emission factors, HGVs from 73 – 108 months produced the most NO_x and HGVs older than 108 months accounted for the most PM_{2.5}.

Without factoring in the vehicle categories, emission percentages across the age groups are relatively balanced; the differences are better illustrated by the absolute values of the amounts of the respective emissions produced. The largest NO_x emission amounts are attributed to vehicles in the age group from 73 – 108 months, which gets tax benefits both in the CR and in Slovakia. The highest values of PM_{2.5} were identified in vehicles older than 108 months, which do not receive any tax benefits in either the CR or Slovakia, whereas in Slovakia vehicles older than 145 months are disadvantaged in terms of taxes. This situation is exacerbated by the state of the fleet in the CR and Slovakia (ACEA, 2019; Eurostat, 2019). The emission factor of CO₂ shows the dominance of vehicles newer than 36 months, which receive the most preferential treatment in the CR and Slovakia, which, according to Pearce (1991), contravenes the principle of correction of distortions.

The loss of around 25% of Czech commercial vehicle data may be considered a limitation of the present study. However, most of the calculated characteristics are expressed as percentages, so this loss resulting from source data bias can be accepted. In the case of absolute emission values, we must bear in mind that the real values may be higher in proportion to the data loss. The parameters of risk described by Lozhkina and Lozhkin (2015) that call for the high quality of source data and manner of its processing were eliminated (or at least minimized to the fullest extent possible).

Conclusion

The present research has identified the qualitative characteristics of the Czech vehicle fleet in the categories of PCs, LCVs, HGVs and STs used for business purposes as well as the parameters of this segment in terms of CO₂, NO_x and

PM_{2.5} emissions with a significant environmental impact under the EEA's (2019) classification. The processing of data from the RMV, VTS and Copert national emission inventory, whose relevance is evidenced by Emisia (2020) and Pelikán and Brich (2018), has identified the absolute values and percentages of frequency of occurrence in age groups, distances traveled by vehicle categories in age groups, emissions per vehicle, kilometers traveled by vehicle categories in age groups, emissions per vehicle considering average distances of vehicle categories in age groups, emissions of vehicle categories in age groups and emissions of vehicles in age groups.

The finding is that the basic descriptive characteristics of Czech fleet vehicles are subject to road tax discord with the results obtained after factoring in the values of the national emission inventory. The total results, without taking into account the affiliation of vehicles to categories in accordance with the conditions of road tax benefits in the CR, emphasize the fact that the most preferential tax treatment is received by vehicles that produce the largest amount of CO₂. Tax benefits may also be applied to vehicles generating the largest amount of NO_x emissions. The system of tax benefits seems adequate only for the PM_{2.5} emission factor. A limitation of the above findings and their applicability is that the unit emissions of these vehicles are favorable, in particular for NO_x and PM_{2.5}.

Based on the findings concerning the state of the fleet (ACEA, 2019; Eurostat, 2019), a reduction of nominal road tax rates in the CR is seen as ineffective and inadequate. Most importantly, it does not correspond to the total production of emissions by the Czech commercial fleet and their serious impact (Mostert, Caris and Limbourg, 2017; WHO, 2018). The findings, formulated procedures and input data should support the reassessment, adjustment or elimination of road tax reduction in the CR. If we assume that the composition and characteristics of the fleet are similar in Slovakia, based on the basic data of the ACEA (2019), EEA (2020), Eurostat (2019) and Friedrich (2011), it follows that the general conclusions formulated for the CR, stating that the preferential tax treatment of newer vehicles is not adequate due to their significant generation of harmful emissions, are also applicable to Slovakia.

The research in the CR has shown that the utilization of data on frequency of occurrence and distance traveled by vehicles in their respective categories and, most importantly, their age groups seems to be essential for the identification of emission parameters and may serve as substantial support for the reassessment of tax policies in accordance with the conclusions of Pui and Othman (2017), Rasool, Zaidi and Zafar (2019) and Santos (2017) in those countries that intend to enhance their fleet parameters, decrease emissions generated by road motor transport and improve the environment while bearing in mind the health of the population.

References

- ACEA (2019): ACEA Reports, Vehicles in Use, Europe 2019. [Cit. 10. 12. 2020.] Available at: <https://www.acea.be/uploads/publications/ACEA_Report_Vehicles_in_use-Europe_2019.pdf>.
- ACEA (2020): ACEA Tax Guide 2020. [Cit. 14. 12. 2020.] Available at: <https://acea.be/uploads/news_documents/ACEA_Tax_Guide_2020.pdf>.
- ACHTNICHT, M. – BUHLER, G. – HERMELING, C. (2012): The Impact of Fuel Availability on Demand for Alternative-Fuel Vehicles. *Transportation Research Part D – Transport and Environment*, 17, No. 3, pp. 262 – 269. DOI: 10.1016/j.trd.2011.12.005.
- ALBERINI, A. – BAREIT, M. – FILIPPINI, M. – MARTINEZ-CRUZ, A. L. (2018): The Impact of Emissions-Based Taxes on the Retirement of Used and Inefficient Vehicles: The Case of Switzerland. *Journal of Environmental Economics and Management*, 88, pp. 234 – 258. DOI: 10.1016/j.jeem.2017.12.004.
- ALBERINI, A. – BAREIT, M. (2017): The Effects of Registration Taxes on New Car Sales and Emissions: Evidence from Switzerland. *Resource and Energy Economics*, 56, pp. 96 – 112. DOI: 10.1016/j.reseneeco.2017.03.005.
- BAGIENSKI, Z. (2015): Traffic Air Quality Index, *Science of the Total Environment*, 505, pp. 606 – 614. DOI: 10.1016/j.scitotenv.2014.10.041.
- BARBIERI, N. (2015): Investigating the Impacts of Technological Position and European Environmental Regulation on Green Automotive Patent Activity. *Ecological Economics*, 117, pp. 140 – 152. DOI: 10.1016/j.ecolecon.2015.06.017.
- BERKOWICZ, R. (2000): OSPM – A Parameterized Street Pollution Model, *Environmental Monitoring and Assessment*, 65, No. 1 – 2, pp. 323 – 331. DOI: 10.1023/A:1006448321977.
- BJERTNAES, G. H. M. (2019): Efficient Combination of Taxes on Fuel and Vehicles. *Energy Journal*, 40, pp. 387 – 408. DOI: 10.5547/01956574.40.SII.gbje.
- CARLING, K. – HÅKANSSON, J. – MENG, X. – RUDHOLM, N. (2017): The Effect on CO₂ Emissions of Taxing Truck Distance in Retail Transports. *Transportation Research, Part A – Policy and Practice*, 97, pp. 47 – 54. DOI: 10.1016/j.tra.2017.01.010.
- COELHO, M. C. – FONTES, T. – BANDEIRA, J. M. – PEREIRA, S. R. – TCHEPEL, O. – DIAS, D. – SÁ, E. – AMORIM, J. H. – BORREGO, C. (2014): Assessment of Potential Improvements on Regional Air Quality Modelling Related with Implementation of a Detailed Methodology for Traffic Emission Estimation. *Science of the Total Environment*, 470 – 471, pp. 127 – 137. DOI: 10.1016/j.scitotenv.2013.09.042.
- CNR (2020): Act No. 16/1993. [Cit. 5. 10. 2020.] Available at: <<https://www.zakonyprolidi.cz/cs/1993-16>>.
- DAVID, P. (2012): Principles of Taxation of Road Motor Vehicles and their Possibilities of Application. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis*, 60, No. 2, pp. 483 – 492. DOI: 10.11118/actaun201260020483.
- DAVID, P. (2015): Fair and Effective Environmental Road Tax on Passenger Vehicles. *Journal of Economics*, 63, No. 5, pp. 524 – 541. Available at: <<https://www.sav.sk/journals/uploads/0620134105%2015%20David%20+%20RS.pdf>>.
- DAVIES WALDRON, CH. (2006): Mobile Combustion. In: EGGLESTON, S. et al. (eds): 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2. Energy, Hayama, Japan: Institute for Global Environmental Strategies, pp. 3.1 – 3.78. [Cit. 28. 11. 2020.] Available at: <https://planning.lacity.org/eir/8150Sunset/References/4.E.%20Greenhouse%20Gas%20Emissions/GHG.27_IPCC%20National%20GHG%20Inventories.pdf>.
- DONG, H. – DAI, H. – GENG, Y. – FUJITA, T. – LIU, Z. – XIE, Y. – WU, R. – FUJII, M. – MASUI, T. – TANG, L. (2017): Exploring Impact of Carbon Tax on China's CO₂ Reductions and Provincial Disparities. *Renewable and Sustainable Energy Reviews*, 77, pp. 596 – 603. DOI: 10.1016/j.rser.2017.04.044.

- EEA (2020): Air Quality in Europe – 2020 Report. Luxembourg: European Environment Agency. [Cit. 10. 12. 2020.] Available at: <<https://www.eea.europa.eu/publications/air-quality-in-europe-2020-report>>.
- EEA (2019): EMEP/EEA Air Pollutant Emission Inventory Guidebook 2019. Luxembourg: European Environment Agency. [Cit. 15. 15. 2020.] Available at: <<https://www.eea.europa.eu/publications/emep-eea-guidebook-2019>>.
- EMISIA (2020): Copert – The Industry Standard Emissions Calculator. [Cit. 2. 12. 2020.] Available at: <<https://www.emisia.com/utilities/copert/>>.
- ESKRIDGE, R. – CATALANO, J. (1987): A Numerical Model for Predicting Air Pollutants Near Highways: User's Guide. Environmental Protection Agency, NC, USA: Research Triangle Park. [Cit. 11. 12. 2020.] Available at: <<https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=2000TJ28.PDF>>.
- EUROSTAT (2019): Energy, Transport and Environment Statistics. [Cit. 10. 11. 2020.] Available at: <<https://ec.europa.eu/eurostat/documents/3217494/10165279/KS-DK-19-001-EN-N.pdf/76651a29-b817-eed4-f9f2-92bf692e1ed9>>.
- FIORITO, G. (2017): Carbon Taxes to Reduce CO₂ Emissions from Road Transport in Italy, *International Journal of Transport Economics*, 44, No. 1, pp. 137 – 152. DOI: 10.19272/201706701007.
- FRIEDRICH, R. (2011): Methods and Results of the HEIMTSA/INTARESE Common Case Study. [Cit. 12. 11. 2020.] Available at: <http://www.integrated-assessment.eu/eu/sites/default/files/CCS_FINAL_REPORT_final.pdf>.
- IPCC (2006): IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston. Hayama, Japan: Iges. [Cit. 19. 11. 2020.] Available at: <https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/0_Overview/V0_0_Cover.pdf>.
- KETZEL, M. – JENSEN, S. S. – BRANDT, J. – ELLERMANN, T. – OLESEN, H. R. – BERKOWICZ, R. – HERTEL, O. (2012): Evaluation of the Street Pollution Model OSPM for Measurements at 12 Streets Stations Using a Newly Developed and Freely Available Evaluation Tool. *Journal of Civil & Environmental Engineering*, 1, No. 4, pp. 1 – 11. DOI: 10.4172/2165-784X.S1-004.
- KIM, Y. D. – HAN, H. O. – MOON, Y. S. (2011): The Empirical Effects of a Gasoline Tax on CO₂ Emissions Reductions from Transportation Sector in Korea *Energy Policy*, 39, No. 2, pp. 981 – 989. DOI: 10.1016/j.enpol.2010.11.026.
- KLIER, T. – LINN, J. (2015): Using Taxes to Reduce Carbon Dioxide Emissions Rates of New Passenger Vehicles: Evidence from France, Germany, and Sweden. *American Economic Journal: Economic Policy*, 7, No. 1, pp. 212 – 242. DOI: 10.1257/pol.20120256.
- KONO, H. – ITO, S. (1990): A Comparison of Concentration Estimates by the OMG Volume – Source Dispersion Model with Three Line Source Dispersion Models. *Atmospheric Environment, Part B. Atmosphere*, 24, No. 2, pp. 253 – 260. DOI: 10.1016/0957-1272(90)90030-X.
- KUKKONEN, J. – HÄRKÖNEN, J. – WALDEN, J. – KARPPINEN, A. – LUSA, K. (2001): Evaluation of the CAR-FMI Model Against Measurements Near a Major Road. *Atmospheric Environment*, 35, No. 5, pp. 949 – 960. DOI: 10.1016/S1352-2310(00)00337-X.
- LIU, J. – SANTOS, G. (2015): Decarbonizing the Road Transport Sector: Breakeven Point and Consequent Potential Consumers' Behavior for the US Case. *International Journal of Sustainable Transportation*, 9, No. 3, pp. 159 – 175. DOI: 10.1080/15568318.2012.749962.
- LOZHKINA, O. V. – LOZHKIN, V. N. (2015): Estimation of Road Transport Related Air Pollution in Saint Petersburg Using European and Russian Calculation Models. *Transportation Research, Part D-Transport and Environment*, 36, pp. 178 – 189. DOI: 10.1016/j.trd.2015.02.013.
- LU, CH. – TONG, Q. – LIU, X. (2010): The Impacts of Carbon Tax and Complementary Policies on Chinese Economy. *Energy Policy*, 38, No. 11, pp. 7278 – 7285. DOI: 10.1016/j.enpol.2010.07.055.

- MARRIOT, L. – MORTIMORE, A. (2017): Missions, Road Transport, Regulation and Tax Incentives in Australia and New Zealand. *Journal of the Australasian Tax Teachers Association*, 12, No. 1, pp. 23 – 52. [Cit. 10. 12. 2020.] Available at: <<https://www.business.unsw.edu.au/About-Site/Schools-Site/Taxation-Business-Law-Site/jattavolumes/2-marriott-and-mortimore-emissions-road-transport-regulation-and-tax-incentives.pdf>>.
- MOSTERT, M. – CARIS, A. – LIMBOURG, S. (2017): Road and Intermodal Transport Performance: The Impact of Operational Costs and Air Pollution External Costs. *Research in Transportation Business and Management*, 23, pp. 75 – 85. DOI: 10.1016/j.rtbm.2017.02.004.
- NTZIACHRISTOS, L. – SAMARAS, Z. (2016): EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016, Update 2018. Luxembourg: European Environmental Agency. [Cit. 10. 12. 2020.] Available at: <<file:///C:/Users/Petr/Downloads/1.A.3.b.i-iv%20Road%20transport%202018.pdf>>.
- NRSR (2020): Act No. 361/2014. [Cit. 14. 12. 2020.] Available at: <<https://www.zakonypreludi.sk/zz/2014-361>>.
- PARRY, I. – HEINE, D. – LI, S. – LIS, E. (2014): How Should Different Countries Tax Fuels to Correct Environmental Externalities? *Economics of Energy & Environmental Policy*, 3, No. 2, pp. 61 – 77. DOI: 10.5547/2160-5890.3.2.ipar.
- PEARCE, D. (1991): The Role of Carbon Taxes in Adjusting to Global Warming, *Economic Journal*, 101, No. 407, pp. 938 – 948. DOI: 10.2307/2233865.
- PELIKÁN, L. – BRICH, M. (2018): Zavedení programu Copert 5 pro výpočet emisí ze silniční dopravy v České republice. Brno: Transport Research Centre.
- PELIKÁN, L. – BRICH, M. – LIČBINSKÝ, R. (2018): Zavedení programu COPERT 5 pro výpočet emisí ze silniční dopravy v ČR: Final Report. Brno: Transport Research Centre, Contracting Authority: Ministry of Transport of the Czech Republic.
- PELIKÁN, L. – BRICH, M. – ŠPIČKA, L. (2017): Nastavení metodických postupů pro sběr a zpracování aktivních dat o vozovém parku v ČR: Final Report. Brno: Transport Research Centre, Contracting Authority: Ministry of Transport of the Czech Republic.
- PUI, K. L. – OTHMAN, J. (2017): Economics and Environmental Implications of Fuel Efficiency Improvement in Malaysia: A Computable General Equilibrium Approach. *Journal of Cleaner Production*, 156, pp. 459 – 469. DOI: 10.1016/j.jclepro.2017.04.067.
- PWC (2019): 2019 Global Automotive Tax Guide. [Cit. 12. 22. 2020.] Available at: <<https://www.pwc.de/de/automobilindustrie/2019-global-automotive-tax-guide.pdf>>.
- RASOOL, Y. – ZAIDI, S. A. H. – ZAFAR, M. W. (2019): Determinants of Carbon Emissions in Pakistan's Transport Sector. *Environmental Science and Pollution Research*, 26, No. 22, pp. 1 – 15. DOI: 10.1007/s11356-019-05504-4.
- SANTOS, G. (2017): Road Transport and CO₂ Emissions: What Are the Challenges? *Transport Policy*, 59, pp. 71 – 74. DOI: 10.1016/j.tranpol.2017.06.007.
- SANDMO, T. (2016): The Norwegian Emission Inventory 2016. Documentation of Methodologies for Estimating Emissions of Greenhouse Gases and Long-Range Transboundary Air Pollutants. Statistics Norway: Oslo-Kongsvinger. [Cit. 12. 12. 2020.] Available at: <https://ssb.brage.unit.no/ssb-xmlui/bitstream/handle/11250/2461056/NOT2016-22_web.pdf?sequence=1&isAllowed=y>.
- SCRIMGEOUR, F. – OXLEY, L. – FATAI, K. (2005): Reducing Carbon Emissions? The Relative Effectiveness of Different Types of Environmental Tax: The Case of New Zealand. *Environmental Modelling & Software*, 20, No. 11, pp. 1439 – 1448. DOI: 10.1016/j.envsoft.2004.09.024.
- SOLAYMANI, S. – KARI, F. (2013): Environmental and Economic Effects of High Petroleum Prices on Transport Sector. *Energy*, 60, pp. 435 – 441. DOI: 10.1016/j.energy.2013.08.037.
- TRC (2019): The Register of Motor Vehicles (RMV). Internal Data.
- TRC (2019a): Copert National Emission Inventory for the CR. Internal Data.
- TRC (2019b): Vehicle Testing Stations (VTS). Internal Data.

-
- UNITED NATIONS (2015): Paris Agreement. [Cit. 15. 12. 2020.] Available at: <http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf>.
- WANG, H. – FU, L. X. – LIN, X. – ZHOU, Y. – CHEN, J. CH. (2009): A Bottom-Up Methodology to Estimate Vehicle Emissions for the Beijing Urban Area. *The Science of the Total Environment*, 407, No. 6, pp. 1947 – 1953. DOI: 10.1016/j.scitotenv.2008.11.008.
- WHO (2018): Global Health Observatory Data Repository, Deaths by Country. [Cit. 10. 12. 2020.] Available at: <<https://apps.who.int/gho/data/node.main.BODAMBIENTAIRDTHS?lang=en>>.
- ZHOU, Y. – FANG, W. – LI, M. – LIU, W. (2018): Exploring the Impacts of a Low-Carbon Policy Instrument: A case of Carbon Tax on Transportation in China. *Resources Conservation and Recycling*, 139, No. 1, pp. 307 – 314. DOI: 10.1016/j.resconrec.2018.08.015.