

OLDER MOTOR VEHICLES AND OTHER ASPECTS WITHIN THE PROPOSAL OF ENVIRONMENTAL TAX IN THE CZECH REPUBLIC

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Abstract

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The article deals with theoretical and practical aspects of introducing environmental road tax for motor vehicles registered in the Czech Republic. The article analyses requirements to be met by this type of tax and reviews its functions. Further it analyses practical aspects in the sense of existence of data that is needed for accomplishing the task to find an ideal form of environmental tax. Based on these foundations, the authors identified a suitable model of taxation of motor vehicles registered in 2000 and after. Another aim was finding proper variables as regards the need of calculation of theoretical emission data in motor vehicles registered in the Czech Republic before 2000. The proposed model is expected to use emission limits as declared in technical documentation of motor vehicles registered after 2000 and theoretical limits calculated by means of variables of engine capacity and time in older motor vehicles despite the fact that these variables provide explanation for the analysed emission effect just in case of 58% diesel engines, more precisely in case of 82% petrol engines.

road tax, engine capacity, fuel consumption, environmental tax

In the Czech Republic, road tax is classified as property tax despite OECD's classification of road tax as consumption tax. In this respect, also expert community does not consider road tax as property tax, or at least a typical property tax. Despite all these aspects of classification, road tax is classified as property tax quite often with respect to similarities in tax techniques used.

The European Commission's aim in the field of taxation of motor vehicles is improving the inner market functioning by means of removing the existing tax hindrances in transferring of passenger motor vehicles within European Union and restructuralisation of tax bases in European Union member countries in the sense of inclusion of CO₂ emissions produced by motor vehicles. It is clear that the aim is neither harmonisation of tax rates, at least for now, nor straightforward obligation to impose new taxes.

Some taxes can be imposed for behavioral purposes. Imposing educational tax involves taxation of consumption or activity the effects of

which are undesirable socially. We assume that tax payers are not aware of these effects and so taxation is used here to put pressure to reduce particular activities or consumption. Education function excludes fiscal function. The aim of education function is not collection of resources. Education based on imposing taxes and thus financial pressure equals to education of less wealthy people and substitutes pressure of sufficient awareness (David, 2009). Education is not a proper reason for imposing any type of tax, not even tax imposed on motor vehicles. Even Proost *et al.* (2009) did not notice any significant decrease in traffic density after taxation of emissions produced by operating motor vehicles was introduced. However, Johansson, Burman and Forsberg (2009) noticed in their experiment they carried out in Stockholm that there was decrease in traffic density after imposing a higher road tax. The result can not be considered as determined by local character of the experiment and also reduction of excessiveness caused by the original ineffective allocation. Function of tax imposed on

operating motor vehicles should be derived from the answer to the question that looks for reasons for taxation of motor vehicles. Operating motor vehicles entails both hidden and visible costs. Pigou distinguished between private benefit and social benefit and this marked the beginning of the issue of externalities (Holman *et al.*, 1999). Santos (2010) presents externalities of road traffic as ecological damage, road accidents, traffic jams and dependence on oil, and these externalities are not taken in consideration in market prices. Solution of externalities should have been reached by the state's intervention into market process by means of a system of taxes and state subsidies with the aim of removing discrepancies between social and private costs. Marginal benefits, as described by Široký *et al.* (2008), are called 'the same victim' by Pigou. This 'victim' is defined by Pigou on the basis of the absolute same victim of tax payers, their marginal victim and the same proportional victim. Imposing a tax should lead to rectifying the damage done by operating motor vehicles. Road tax should fulfill rehabilitation function in the first place. Some other functions of tax can be fulfilled at the same time but they must not disrupt the process of fulfilling rehabilitation function.

Taxation of motor vehicles should meet requirements that are expected to be met by taxation.

Tax effectivity lies in individuals' paying the full costs of their consumption. If consumption of an individual shifts costs onto others, then the others have to pay part of this consumption. This 'burden' is called negative externality. In such a case, taxes can be used for correction of negative externalities and ensuring the economic effectivity in this situation (David, 2012). Tax should reach marginal costs of operators or users of motor vehicles where it is necessary to include marginal social costs of operating motor vehicles. In that case the situation can be called economically effective. Setting net social costs of using motor vehicles should be key for establishing the form and extent of their taxation. Setting social costs of operating motor vehicles is not an easy task to do, if not impossible. Cnossen (2005) states, however, that important externalities can be quantified in this sphere and abstracted from less important impacts. This statement is in accord with second best tax policies.

The aim of this text is to identify a proper quantification model of road tax base on the basis of relevance verification of imposing environmental tax on motor vehicles.

METHODS AND RESOURCES

Verification of relevance of environmental taxation will be done on the basis of standard general methods of scientific work. Subsequently, it is important to work with revised data (Turčíněk, 2012) provided by the Ministry of the Interior on registered passenger motor vehicles (MVCR, 2012)

using emission levels data available in Vehicle Certification Agency database (2012). In motor vehicles registered from 2001 it is possible to assign emission levels data on the basis of agreement between individual types and makes of the motor vehicles. Other available characteristics are average consumption, engine capacity (cm³) and year of the first registration. These characteristics can be then used for quantification of emission levels data in motor vehicles older than 2001 as emission levels data is missing in motor vehicles registered before this year.

Within the analysed sample of motor vehicles registered from 2001 to 2011 in the Czech Republic, we will use a correlation analysis with the aim of creating correlation matrix and finding dependence of random variables of the sample. Using this data and statistical software STATISTICA 9.0 we will define a proper model for regression analysis the result of which will be equations for measuring approximate levels of CO₂. The CO₂ levels will then form a basis for the suggested reform of motor vehicle taxation.

RESULTS AND DISCUSSION

The form of taxation, or rather change in taxation of motor vehicles does not necessarily have to impact collection of these taxes, as supported by England and Carlson (2008). On the other hand, it is suitable that an additional taxation burden is formed on condition that the existing taxation amount does not correspond with social costs of operating motor vehicles. This enables to create a yield-neutral model of taxation of motor vehicles. According to Auerbach and Feldstein (2002), the total additional burden will depend on the amount of tax and cross-elasticity of demand.

There are often solution suggestions that deform market, for example in Sergeant *et al.* (2008), who within reduction of air pollution suggest introduction and raising of parking fees, transit tolls, or permission for entry into chosen localities. At the same time these authors also show a far better option in the form of offering good quality environment-friendlier alternative forms of transportation of passengers and goods. However, this offer can be considered a suitable complement to a properly set tax on operating motor vehicles.

Given the identified requirements that are expected to be met by tax imposed on motor vehicles and functions of the tax, it is clear that the principal aspect to be included into calculation of tax obligation is emissions produced by motor vehicles. As emissions are produced by all motor vehicles, the first requirement for taxation of operating them must be generality. Taxation must apply to all motor vehicles, both motor vehicles used for business purposes and privately used motor vehicles if they are producers of emissions.

Aside from some not very important connections with ecological impact of operating motor vehicles,

in the Czech Republic there is no direct connection between emissions produced by motor vehicles and their taxation amount. The closest relation to taxation of real emissions has the fee for the first registration of a used vehicle in the Czech Republic on the basis of emission class. Other provisions with ecological aspect use just substitute features which can be considered neither efficient nor fair. What is more, motor vehicles in the Czech Republic are subject to tax on the basis of selection and substitute features, which more or less do not correspond with the identified need of environmental character of tax. In the modified form of the concerned law there are some regulations that favour motor vehicles that produce less emissions, however, it is still the case of using substitute features of real emissions.

Emission attributes of motor vehicles can be included into tax calculation in more ways. It is possible to use affiliation of motor vehicles with emission classes based on EURO limits, real emissions of a particular make and type of motor vehicle, or real amount of emissions produced per a time unit. Connection of road tax rates and the relevant emission class EURO of a particular motor vehicle based on its technical documentation seems to be an easy form of environmental taxation of motor vehicles. Unfortunately, this form hardly shows real amount of emissions produced by a particular motor vehicle. The main reason is the range of emission classes EURO, which would result in the same taxation of motor vehicles with very different real emission levels. This would distort automobile market just like in the case of step progression in income taxation. Furthermore, this alternative does not consider real emission levels in relation to motor vehicle use. A rarely used motor vehicle classified as a low EURO limit can produce far less emissions than a motor vehicle in a higher EURO class that is used heavily.

Inclusion of emissions of a particular make and type of motor vehicle based on technical documentation is a step forward compared to the previous model. This model eliminates possible distortions and takes more consideration of environmental impacts. However, it does not look at real amount of emissions in relation to the extent of motor vehicle use, just like the previous model.

An alternative from the point of effective taxation of impact of operating motor vehicles is a model that incorporates emissions of a particular make and type of motor vehicle together with the number of kilometres travelled per a particular period of time. This enables inclusion of real emissions produced by that motor vehicle per a particular period of time and eliminates potential unfairness that stems from different extents of motor vehicle use.

The last and from the point of taxation of emissions produced by operating motor vehicles ideal alternative is a model that identifies and taxes real amount of emissions produced by a motor vehicle registered in the Czech Republic. This model is based on a principal of direct measurement

of emissions in every single motor vehicle for the whole fixed period of time and taxation of the total real emission amount in this period. None of the existing tax systems – annual road tax, consumption tax on mineral oils and registration tax, can be considered a perfect system of paying for harmful consumption, or using motor vehicles. If we abstract away from other but emission impacts of operating motor vehicles like wear of infrastructure, noise or accident rate, there are theoretical possibilities of ideal taxation of motor vehicles. To measure real emissions in every single motor vehicle would mean to have a highly sophisticated and technologically advanced system (Borger and Mayeres, 2006). Real amount of emissions produced could be measured by a measuring instrument built into a motor vehicle. A technological instrument for making this possible would have to meet requirements of cost effectiveness, reliability, abuse resistance and protection of personal data (Santos *et al.*, 2010). This way, however, appears to be costly and prone to tax evasion. As an alternative can be considered application of annual road tax in combination with real number of kilometres travelled in a particular motor vehicle. There are three hindrances to this system. Using figures measured by the measuring instrument can be prone to tax evasion. In case of satellite localisation, distance tracking can endanger personal data privacy. In addition, this system does not consider real emissions, it is based on substitute features of emissions. Real emissions are considerably influenced by such factors as vehicle type, motor vehicle weight, speed, fuel, engine adjustment, catalytic convertor effectiveness, age of motor vehicle and its maintenance, air temperature, road condition, terrain and road maintenance (Adamec, 2005).

It is necessary to say that a system of annual road tax, which takes account of emissions emitted per kilometre, presents the best alternative for taxation of negative effects caused by operating motor vehicles – emissions. This system is not prone to tax evasion and tax base is based on the amount of emissions emitted per kilometre. However, annual road tax does not take account of real number of kilometres travelled by that motor vehicle and the actual condition of that vehicle. The result is that it can not provide accurate data of the real amount of emissions emitted. Effective emission reduction can be questioned also despite study of Blanc and Derkanne (2010) that prove this effect. Regressive impact of annual road tax is undeniable, but this negative side can be easily compensated by other taxes designed for this purpose. What can the emission data and their use look like in the case of setting environmental road tax? It can look easy in motor vehicles whose producers declare their emissions in their registration document. It is enough to set annual road tax rate per a gram of the declared emission which should correspond with principles and functions this tax is expected to fulfill. However, not all registration documents

provide emission data. Emission data have been provided since 2001. It is not possible to calculate tax amount for motor vehicles registered before this year, and these motor vehicles present the highest portion of passenger motor vehicles in the Czech Republic. It is therefore necessary to quantify emission levels in these motor vehicles as a completely different principle of taxation of motor vehicles of various ages might cause severe deformations.

First, we carry out a correlation analysis in Tab. I and Tab. II which will produce a correlation coefficient that shows linear dependence of random quantities. The analysis is carried out separately for diesel and petrol engines with regards to different technological and also emission parameters.

Building correlation matrix for diesel-powered passenger motor vehicles is based on a sample of all 8 391 types of all registered makes of diesel-powered motor vehicles in the Czech Republic. What we can see is that correlation coefficient between consumption and CO₂ emissions is higher than 0.97. That is quite a high figure as the span of correlation coefficient is between -1 and 1 and marginal figures are reached in the case of linear dependence which can be described in a formula and does not need to be estimated. Correlation coefficient between engine capacity and CO₂ emissions is 0.76, and it is rule in the majority of diesel-powered engines that the bigger the engine capacity is, the greater amount of CO₂ emissions is released. This proportion does not necessarily need to be linear, but a medium strong relation is evident here.

Correlation matrix built for passenger motor vehicles with petrol engine is based on sample of 14 454 types of all registered makes of petrol motor vehicles in the Czech Republic. The result shows that the amount of CO₂ emissions emitted is in petrol motor vehicles strongly linearly dependent on consumption. Slightly smaller dependence can be seen between engine capacity and CO₂ emissions amount.

Quite on the contrary, the year has a weak indirect dependence on the amount of CO₂ emissions emitted. This corresponds with technological trends in motor vehicle production when producers work in a concerted effort to decrease consumption of motor vehicles and subsequently also CO₂ emissions. We provide a graph for illustrating the given and commented results of correlation matrix. It is obvious that the plotted figures of all registered types of motor vehicles in the Czech Republic correspond with the previous results.

Fig. 1 shows CO₂ emissions in relation to consumption in all types of motor vehicles registered in the Czech Republic between 2000 and 2011. The data are divided on the basis of engine type into petrol and diesel. The graph shows the total of 8,391 figures of diesel-powered motor vehicles and 14,454 motor vehicles with petrol engine.

The best possible indicator for quantifying emissions is consumption of a particular make and type of motor vehicle. These data are, however, not provided in older motor vehicles and it is necessary to find another useful alternative. All data available on motor vehicles registered before 2001 indicate that we will be forced to use engine capacity as this alternative. Let us see what results on emissions come out of calculation based on engine capacity when compared to real emissions or average consumption of a motor vehicle.

Fig. 2 compares CO₂ emissions and engine capacity of all types of motor vehicles registered in the Czech Republic between 2000 and 2011. The data are divided on the basis of engine type. The file contains all makes and types of motor vehicles just like the previous graph element in this text. What can be seen is that in the case of using engine capacity, dependence is not that striking and so the acquired results can not be as accurate as in the case of using consumption.

As our goal is to estimate the amount of CO₂ produced by motor vehicles that fail to provide these data, we will carry out a regression analysis

I: Correlation matrix for diesel-powered passenger motor vehicles

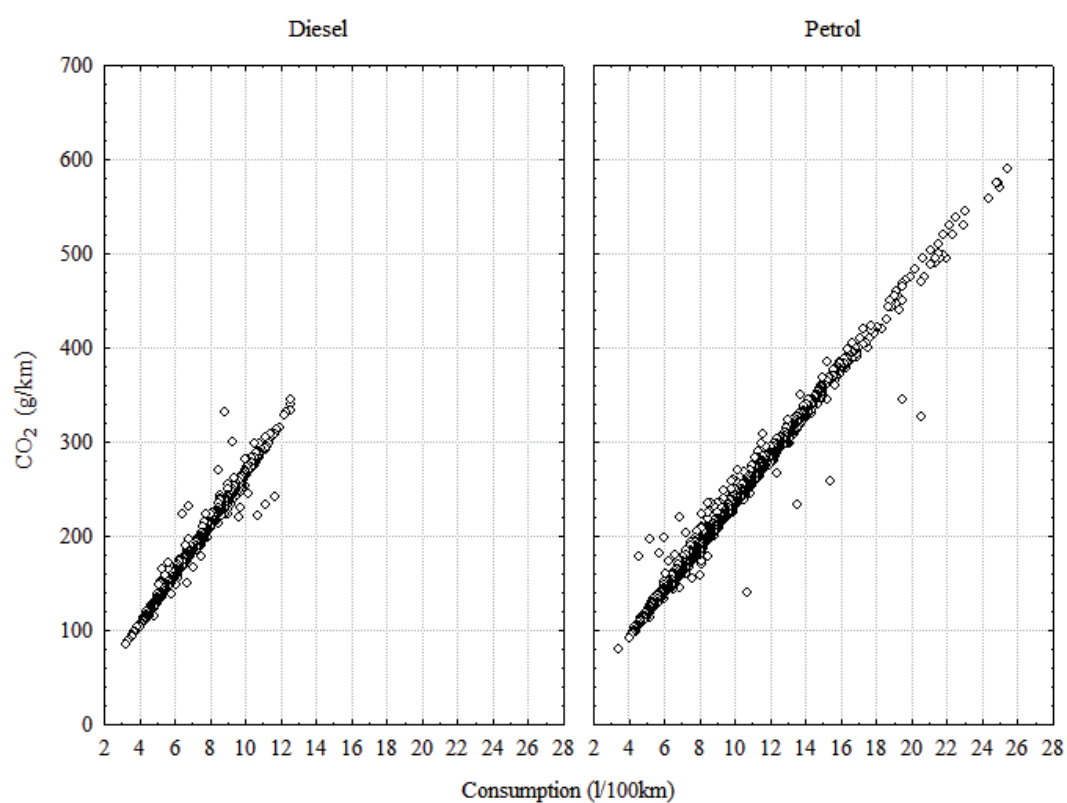
Variable	Average	Standard deviation	Year	Engine capacity	Consumption	CO ₂
Year	2006.841	3.2095	1.000000	-0.018741	-0.129817	-0.159534
Engine capacity	2106.434	472.1098	-0.018741	1.000000	0.739993	0.749747
Consumption	6.482	1.5456	-0.129817	0.739993	1.000000	0.976660
CO ₂	172.125	40.2644	-0.159534	0.749747	0.976660	1.000000

Source: authors

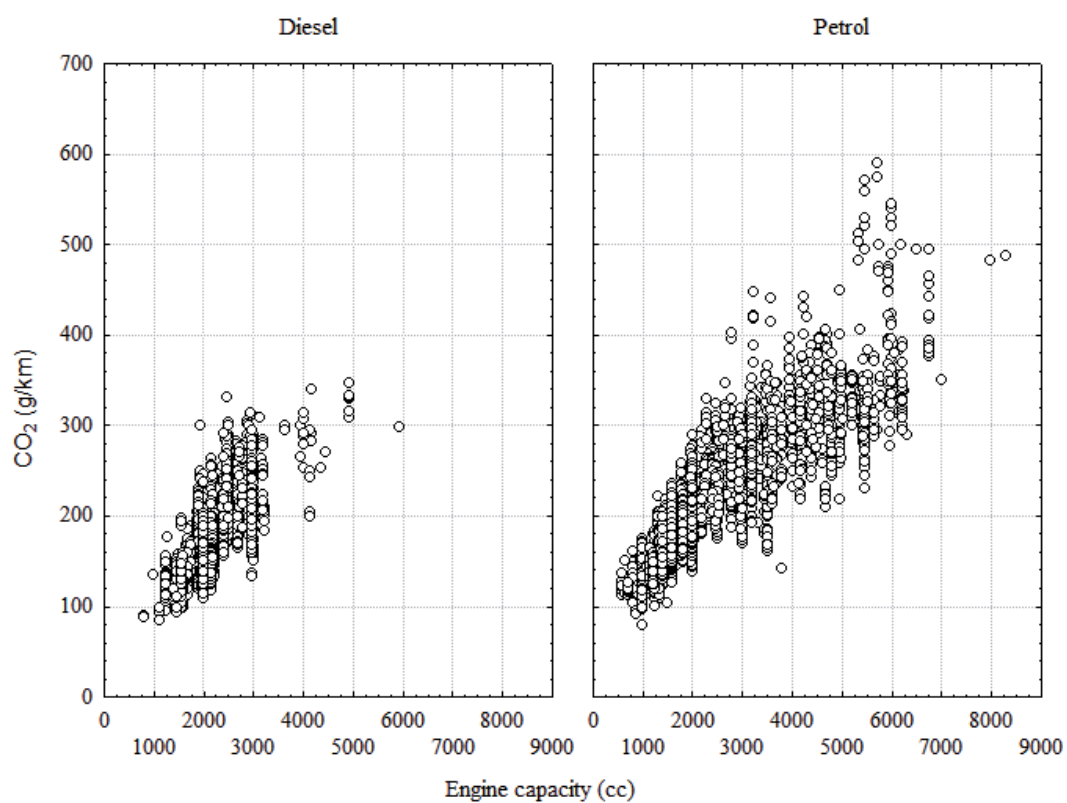
II: Correlation matrix for passenger motor vehicles with petrol engine

Variable	Average	Standard deviation	Year	Engine capacity	Consumption	CO ₂
Year	2005.525	3.550	1.000000	0.042459	-0.161568	-0.180661
Engine capacity	2226.360	1048.273	0.042459	1.000000	0.870008	0.868218
Consumption	8.773	2.415	-0.161568	0.870008	1.000000	0.997564
CO ₂	209.093	57.484	-0.180661	0.868218	0.997564	1.000000

Source: authors



1: Relation of CO₂ emissions and consumption
Source: authors



2: Relation of CO₂ emissions to engine capacity
Source: authors

III: Regression analysis using consumption for diesel-powered passenger motor vehicles

N = 8 391	b*	Std. Err. of b*	b	Std. Err. of b	p-value
Abs. mem.			7.20809	0.407087	0.00
Consumption	0.976660	0.002345	25.44356	0.061093	0.00

Source: authors

IV: Regression analysis using consumption for passenger motor vehicles with petrol engine

N = 14 454	b*	Std. Err. of b*	b	Std. Err. of b	p-value
Abs. mem.			0.77594	0.125692	0.00
Consumption	0.997564	0.000580	23.74524	0.013813	0.00

Source: authors

using linear regression function. We will define regression function for calculating CO₂ emissions from consumption.

Tab. III uses the same sample as in the previous parts of the text within diesel-powered passenger motor vehicles registered in the Czech Republic for estimating the amount of CO₂ emissions produced on the basis of consumption of these vehicles. Coefficient of determination is 0.9539 and determinative mistake of estimate is 8.64. Coefficients of linear regression line can be determined from the parametres in column *b*. What we get is the following equation:

$$Ed^* = 7.20809 + 25.44356 \times Cd^{**},$$

* amount of emissions produced by a diesel engine,

** consumption of a diesel-powered motor vehicle.

Variability of consumption *Cd* explains the amount of emissions produced by diesel engines *Ed* out of 95.39%, the remaining percentage is determined by other influences as follows from the coefficient of determination. The estimate error of CO₂ emissions is less than 8.64 g/km in the majority of samples. *P-value* shows degree of probability that the corresponding coefficient is truly zero and the estimated value is in fact determined by chance. In both input variables we can see that probability of zero coefficient is less than one per cent. Determinative mistakes in coefficients also determine maximum mistakes in coefficient estimates. We can see that value of maximal absolute member ranges between 6.801003 and 7.615177. Similar can be seen in the coefficient of consumption. Values in columns marked with a star * give estimated data on condition that the absolute member is zero, but this is not anticipated in our model.

Just like in the previous parts of the text, also Tab. IV uses the same sample within petrol engines in passenger motor vehicles registered in the Czech Republic for estimating the amount of CO₂ emissions produced on the basis of consumption of these motor vehicles. Coefficient of determination is 0.9951 and determinative mistake of estimate is 4.01. Parametres in column *b* can be used for determining coefficient of linear regression line.

Within motor vehicles with petrol engine, the regression equation for estimating CO₂ emissions by means of a random variable determining consumption is similar:

$$Ep^* = 7.7594 + 23.74524 \times Cp^{**},$$

* amount of CO₂ emissions produced by a petrol engine,

** consumption of passenger motor vehicles with petrol engine.

Variability of consumption *Cp* explains the amount of emissions produced by petrol engines *Ep* out of 99.51%, the remaining percentage is determined by other influences as follows from the coefficient of determination. Zero coefficient probability is again very small and we can anticipate that both the absolute member and coefficient in consumption variable are significant. Based on determinative mistakes of coefficients, estimate accuracy is much better in petrol engines.

We can see in both cases that it is possible to estimate the amount of CO₂ emissions from consumption. However, this does not work on the scale of all registered motor vehicles in the Czech Republic as consumption data are not available in older motor vehicles and new vehicles provide both consumption data and the amount of CO₂ emissions emitted. We know from correlation matrix that a similar dependence on the amount of CO₂ emissions, although weaker, can be seen in a variable that determines engine capacity. We establish regression lines which determine the amount of CO₂ emissions in dependence on engine capacity.

Using a sample of diesel-powered motor vehicles registered in the Czech Republic in Tab. V we estimate the amount of CO₂ emissions on the basis of engine capacity of a particular motor vehicle. Coefficient of determination is 0.5621 and determinative mistake of estimate is 26.645. Parametres in column *b* can be used for determining coefficient of linear regression line. The result is the following equation:

V: Regression analysis using engine capacity for diesel-powered passenger motor vehicles

N = 8 391	b*	Std. Err. of b*	b	Std. Err. of b	p-value
Abs. mem.			37.43320	1.330116	0.00
Engine capacity	0.749747	0.007225	0.06394	0.000616	0.00

Source: authors

VI: Regression analysis using engine capacity for passenger motor vehicles with petrol engine

N = 14 454	b*	Std. Err. of b*	b	Std. Err. of b	p-value
Abs. mem.			103.0949	0.556963	0.00
Engine capacity	0.868218	0.004127	0.0476	0.000226	0.00

Source: authors

$$Ed_1^* = 37.43320 + 0.06394 \times ECd^{**},$$

*the amount of CO₂ emissions produced by a diesel engine,

**engine capacity of a diesel-powered motor vehicle.

Variability of emissions produced by diesel engines ECd explains the amount of emissions produced by diesel engines Ed_1 out of 56.21%, the remaining percentage is determined by other influences as follows from the coefficient of determination. This result is not ideal that is why we will try to estimate more accurately. It is not possible to compare determinative mistakes with the previous results as there is change in independent variable, or rather its unit of measurement. In both input variables we can see that probability of zero coefficient is less than one per cent.

The same procedure is taken in the sample of passenger motor vehicles with petrol engine in Tab. VI and there is a chance to estimate the amount of CO₂ emissions on the basis of consumption of these motor vehicles. Coefficient of determination is 0.7538 and determinative mistake of estimate is 28.524. Equation for quantification of CO₂ emissions on the basis of engine capacity of a particular motor vehicle derived from the figures in column b is as follows:

$$Ep_1^* = 103.0949 + 0.0476 \times ECp^{**},$$

*the amount of CO₂ emissions produced by a petrol engine,

**engine capacity of a motor vehicle with petrol engine.

Variability of engine capacity of a motor vehicle ECp explains the amount of CO₂ emissions produced by petrol engines Ep_1 out of 75.38%, the remaining percentage is determined by other influences as follows from the coefficient of determination. Estimates within petrol engines are far more accurate than in diesel engines just like in the case of including variable of consumption as follows from the coefficient of determination, determinative mistakes of estimate and individual coefficients. In both input variables we can see again that probability of zero coefficient is less than one per cent.

Results of the analysis using engine capacity are worse than if we had consumption data, however, it is still the best feasible method of estimating CO₂ emissions. To get more accurate estimates, we include another available variable that provides the year of first registration of a particular make and type of a motor vehicle into regression equations. Correlation matrix shows that the year of production has a weak indirect linear dependence on the amount of CO₂ emissions. This corresponds with technological effort of automobile producers to decrease consumption and consequently also the amounts of CO₂ emissions produced. As Fig. 3 shows, the year of production is a significant quantity and it is useful to include it into our model.

Fig. 3 uses the same sample of motor vehicles with diesel and petrol engines registered in the Czech Republic. This graph also clearly illustrates relevance of using the factor of year of first registration of motor vehicles for needed estimates of CO₂ emissions of particular types and makes of motor vehicles registered in the Czech Republic. We intend to prove this relevance by means of the following calculations.

For complexity of judging parameters of motor vehicles by means of linear regression analysis, we form equation which shows in Tab. VII the amount of CO₂ emissions in dependence on two random quantities, first consumption of a motor vehicle and the year of first registration of the motor vehicle in the Czech Republic.

Coefficient of determination using the variables of time and consumption in diesel engines is calculated for 0.9550 and determinative mistake of estimate is 8.5466. Equation for diesel engines reads the following:

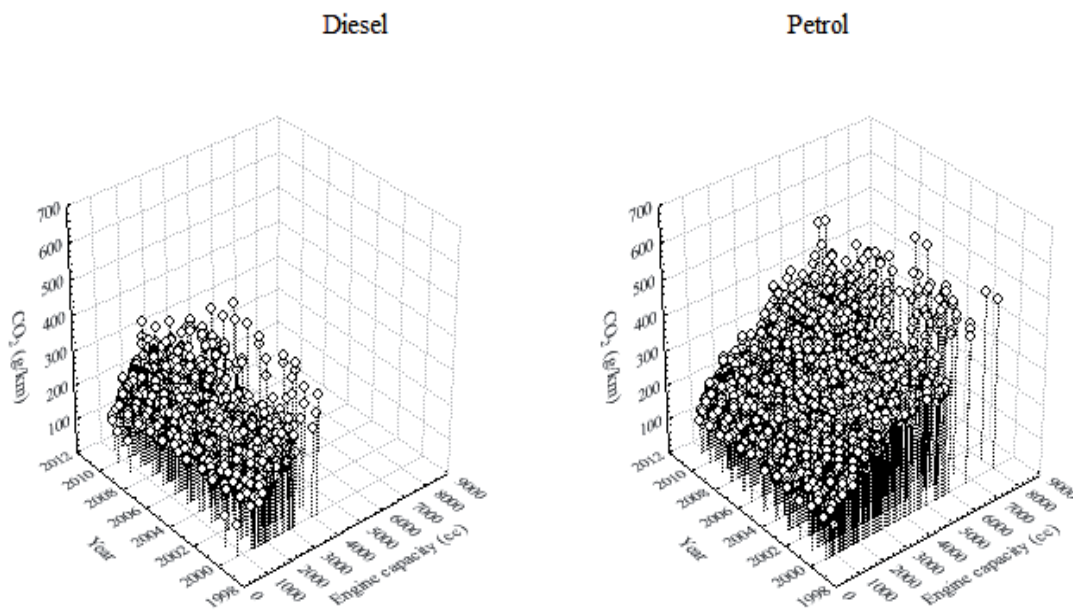
$$Edy^* = 846.5454 + 25.3309 \times Cd^{**} - 0.4179 \times Y^{***},$$

*the amount of emissions produced by a diesel engine,

**consumption of a diesel-powered motor vehicle,

***is year of first registration of a particular type and make of a motor vehicle in the Czech Republic.

Variability of consumption Cd and year Y explains the amount of emissions produced by diesel engines Edy out of 95.5%, the remaining percentage is determined by other influences as



3: Relation of CO₂ emissions to engine capacity in motor vehicles with diesel and petrol engines including the factor of time
Source: authors

VII: Regression analysis using consumption and time for diesel-powered passenger motor vehicles

	N = 8 391	b*	Std. Err. of b*	b	Std. Err. of b	p-value
Abs. mem.				846.5454	58.89398	0.00
Year		-0.033309	0.002337	-0.4179	0.02932	0.00
Consumption		0.972336	0.002337	25.3309	0.06089	0.00

Source: authors

VIII: Regression analysis using consumption and time for passenger motor vehicles with petrol engine

	N = 14 454	b*	Std. Err. of b*	b	Std. Err. of b	p-value
Abs. mem.				651.2488	18.33653	0.00
Year		-0.020008	0.000564	-0.3240	0.00913	0.00
Consumption		0.994331	0.000564	23.6683	0.01343	0.00

Source: authors

follows from coefficient of determination. We see that adding another variable in the model results in improvement of estimate accuracy, although in case of diesel engines with one more dependent variable of consumption this increase is insignificant. The probability of zero coefficient is less than one per cent. Coefficient of determination rose by a mere 0.0011 after adding the variable of year of production.

Coefficient of determination including the variables of time and consumption in petrol engines is 0.9955 and determinative mistake of estimate is 3.8466. Equation for petrol engines derived from figures in column *b* of Tab. VIII is as follows:

$$\text{Epy}^* = 651.2488 + 23.6683 \times \text{Cp}^{**} - 0.3240 \times \text{Y}^{***},$$

*the amount of emissions produced by a petrol engine,

**consumption of a motor vehicle with petrol

engine,

***year of first registration of a particular type and make of a motor vehicle in the Czech Republic.

Variability of consumption *Cp* and year *Y* explains the amount of emissions produced by petrol engines *Epy* out of 99.55%, the remaining percentage is determined by other influences as follows from coefficient of determination. The probability of zero coefficient is again less than one per cent.

Adding the variable of year of production resulted in improving estimate accuracy.

We see that adding the year of production in the model that uses data on consumption enables more accurate estimates which must be appreciated especially within diesel engines where more accurate calculations are required. However, when we use consumption as an explanatory variable, this improvement is not significant. The reason might be the fact that the original estimates are more or less

IX: Regression analysis using engine capacity and time for diesel-powered passenger motor vehicles

N = 8 391	b*	Std. Err. of b*	b	Std. Err. of b	p-value
Abs. mem.			3702.028	177.5148	0.00
Year	-0.145534	0.007050	-1.826	0.0884	0.00
Engine capacity	0.747020	0.007050	0.064	0.0006	0.00

Source: authors

X: Regression analysis using engine volume and time for passenger motor vehicles with petrol engine

N = 14 454	b*	Std. Err. of b*	b	Std. Err. of b	p-value
Abs. mem.			7179.099	120.5438	0.00
Year	-0.217918	0.003712	-3.529	0.0601	0.00
Engine capacity	0.877471	0.003712	0.048	0.0002	0.00

Source: authors

accurate. However, for the above mentioned reasons the estimate needs to be modified and derived from engine capacity where worse estimate accuracy must be anticipated and so inclusion of the variable of time is required.

Coefficient of determination in diesel-powered motor vehicles using the variable of time and engine capacity in Tab. IX is 0.5833, determinative mistake of estimate is 25.995. Parametres in column *b* can be used for setting coefficients of linear regression line and so we get an equation for diesel engines which reads:

$$Edy_1^* = 3702.028 + 0.064 \times ECd^{**} - 1.826 \times Y^{***},$$

*the amount of emissions produced by a diesel engine,

** engine capacity of a diesel-powered passenger motor vehicle,

***year of first registration of a particular type and make of a motor vehicle in the Czech Republic.

Variability of engine capacity *ECd* and year *Y* explains the amount of emissions produced by diesel engines *Edy₁* out of 58.33%, the remaining percentage is determined by other influences based on the coefficient of determination. Adding the year of production in the model with engine capacity enables a more accurate estimate. The final equation shows CO₂ emissions 2.12% better than the original model. It may seem that this improvement is not very significant, but at a look at *p-value* column we see that the variable *Year* is significant.

In case of petrol engines using the variables of year and engine capacity the coefficient of determination in Tab. X is 0.8012 and determinative mistake of estimate is 25.632. Equation for petrol engines reads as follows:

$$Epy_1^* = 7179.099 + 0.048 \times Ecp^{**} - 3.529 \times Y^{***},$$

*the amount of emissions produced by a petrol engine,

** engine capacity of a motor vehicle with petrol engine

***year of first registration of a particular type and make of a motor vehicle in the Czech Republic.

Variability of engine capacity *Ecp* and year *Y* explains the amount of emissions produced by petrol engines *Epy₁* out of 80.12%, the remaining percentage is determined by other influences as follows from coefficient of determination. In case of petrol engines we can see that the variable of the year of production improved the estimate by almost 5% which is significant in comparison with the previous methods of analysis. In both input variables we can see that probability of zero coefficient is less than one per cent.

What we can see is that adding the variable of time makes the final value of all equations increase while the determinative mistake decreases. That is why time is a good variable and has a good influence on the achieved data. In case of diesel the equation corresponds with the data only in 58% which does not make it an accurate estimate and it is recommended to find more data the inclusion of which in the model would contribute to better accuracy.

One possible way of improving estimate accuracy is determination of numerosity of types of motor vehicles as we suppose that some types of motor vehicles with extreme values and decreasing estimate value occur in smaller numbers than other types of motor vehicles. Determining the number of registered motor vehicles of all types would strongly raise the number of samples and this would give us more accurate regression lines. This will be another task of the research team as part of searching for the best feasible model of inclusion of emission element into taxation of passenger motor vehicles in the Czech Republic.

SUMMARY

Within taxation of motor vehicles in the Czech Republic it is necessary to distinguish the above analysed environmental damage caused by operating motor vehicles and other social costs connected with infrastructure, property and health damage. From this point of view, it is highly recommended to preserve the modified form of the existing road tax used for collecting money for other but environmental reasons. The needed modifications include especially generalisation of tax duty, removing signs of taxation of environmental impacts and revision of relevance of substitute features of tax base in motor vehicles. These steps are expected to lead to higher degree of fairness and simplification of the existing form of tax, and last but not least collection of adequate resources with regards to the identified needs. At the same time, it is necessary to impose environmental tax on emissions produced by motor vehicles, which is implied by the analysis carried out. At present, unfortunately, it is not possible to impose the above identified tax model. As the best feasible tax model can be considered the periodic alternative of tax which takes account of real emissions of a particular make and type of motor vehicle as showed in technical documentation within motor vehicles registered since 2001 and the calculated amount of CO₂ emissions on the basis of regression analysis using engine capacity and year of first registration in motor vehicles produced before 2001. This model of identifying emissions explains the analysed effect in diesel-powered motor vehicles in 58% and in motor vehicles with petrol engine in 82%. The results are not ideal, but as the variable of engine capacity is apart from time the only available and relevant variable, it is necessary to rely on it. It is also possible to use the suggested improvement by means of including numerosity of particular makes and types. Collection of the newly introduced tax should with regards to consumption of a stable tax setting with no unexpected changes behave in an environment-negative way with later neutrality tendencies. More importantly, it should be used for rehabilitation of damage caused by operating motor vehicles in accordance with the identified functions and principles of this type of tax.

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