Transport, Energy, Externalities and their Relation to Economic Output

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***Abstract*—**The transport system has a strong relationship to economy, life quality and environment. The economy with high level of division of labour would not be productive enough without efficient transport systems. However, they require increasing transport capacity and have impact on the environment and power supply. It is a proved fact, that countries with more liberal economy are economically stronger (the relation between the index of economic freedom and the gross domestic product). But the question is what the consequences for other human activities are and whether in the transportation we can use the so called Kuznets curve, which predicates that the environmental impacts decrease with the increasing wealth. We particularly examine the relationship between emissions from road transport in the Czech Republic and in 16 European countries and their economic output expressed by the GDP. This relation is known as the Kuznets environmental curve and it claims that from a certain level of welfare the human impacts on the environment decrease.

***Keywords*—**Emissions, energy, environmental Kuznets curve, externality, GDP, transport system.

I. Introduction

THE transportation has been during the whole history basic driver of the human society. It determinated not only the location of towns, but also their internal form and last but not least it was the basic element of the economic development as the inevitable presumption of the goods barter.

The close relationship between transport and economy can be demonstrated during the centuries of human existence by many examples. The transport is on of the basic elements of the trade and the trade (i.e. barter of goods) is besides the natural resources or human capital the next source of the wealth of societies, what follows on the simple law of comparative advantages.

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The Fig.1 shows how countries can move from one consumption possibilities curve to another one, when they use the bilateral trade and so they utilize from the division of labour. This principle helped in the past many countries to the wealth and it has still been helping (what is of course true not only for the national economies, but for individuals or firms). So China could enjoy prosperity at the time of existence of the Silk trail as well as the states around the Mediterranean Sea that could use the maritime transport for their trade. The railway connecting the east with the west of the USA fastened the colonisation of the area. Today this mutual dependence is also large and it has been used by still more countries since the time of the industrial revolution, that made possible to build the infrastructure essentially independently of natural disposals.

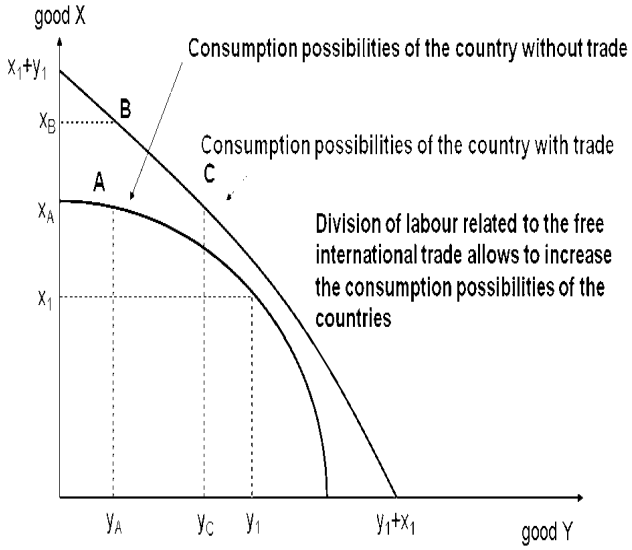

Figure 1: Principle of comparative advantages

The principle of the industrial revolution, consisting of the higher use of the division of labour, was already described in the second half of the 18th century by the Scottish economist Adam Smith (1723 – 1790) in the book Inquiry on the nature and origin of the wealth of. The division of labour increases the output of the economy, so the higher is the degree of the division of labour, the more is the need of a high efficient transport system. This is why during the Medieval Ages

countries with access to sea were richer, because they could use for the trade the then dominating naval transport. That is why Adam Smith was opponent of all state interventions, limiting the free trade among states.

II. Transport and Life Quality

The transport system also substantially affects life quality, especially in towns. The life quality is of course very questionable concept, due to many factors (partly highly subjective), affecting finally the resulting life quality. From many approaches and models we can demonstrate the complexity of the problem on the approach of Ruut Veenhoven [1] that divided the life quality on inner and outer one and classified this concept according the following Table 1.

Table 1: The four qualities of life [1]

4 qualities of life	Outer qualities	Inner qualities
Life chances	Liveability of environment	Life-ability of the person
Life results	Utility of life	Appreciation of life

From the indicated approach it unambiguously follows (and other models would confirm it) that the influence of economic factors and other hard ones will be limited and the life quality will be affected by many other, subjective impacts. From the viewpoint of the transport system the link to the first quadrant will be interesting – thus how the transport system influences the environment that afterwards affects the life quality. The externalities will have a significant influence, whether the negative or positive ones. The relation between the output of the transport system and gross domestic product will be also important.

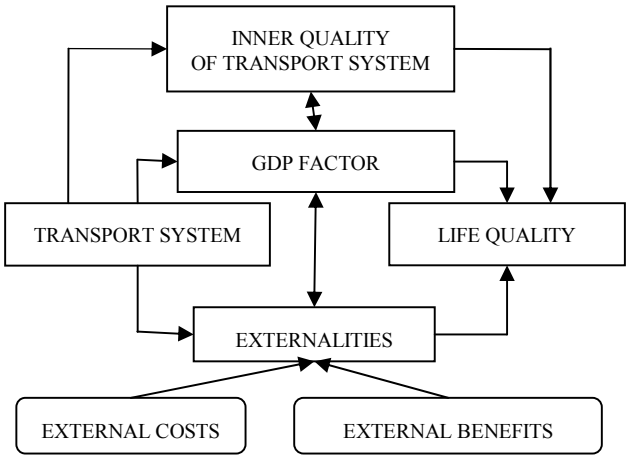

Figure 2: Relation between transport system and life quality

A separate problem will be also the influence of the quality of the actual transport process. If we consider the transport system as a whole (transport quality is usually associated only with public transport), we can also distinct the inner quality that is a set of constituent quality factors, i.e. accessibility, accuracy, comfort, information availability etc. and that can be expressed by the final utility of a passenger. This inner quality will be limited by the GDP indicator that influences the living standard and indirectly the quality of transport means and infrastructure. As outer quality we will call the influence of the transport system on its neighborhood and thus also on its indirect users. This influence is represented by externalities. This relationship can be represented in a simplified way by the scheme in Fig. 2.

III. Economic Freedom, GDP and Transport

The possibility to barter free is also one of factors influencing the so called index of economic freedom (IEF), published by the Heritage Foundation. This index comprises i.a. especially the freedom of trade, but also the range of the state sector or the observance of the human rights. It results explicitly from the various data compared with the GDP of respective countries, that the greater is the economic freedom, the higher is also the gross domestic product of the countries.

The higher GDP needs greater economic freedom. And probably this always used to be so in the history. Another problem is how the economic growth influences other parameters, mainly the environment. As for the transport, it is especially interesting to follow up the relation of the GDP and the development of the individual motoring that has the largest environmental impacts. By the comparison of the particular countries we can find the relation between passenger car transport output and GDP per capita, as shown in Fig. 3.

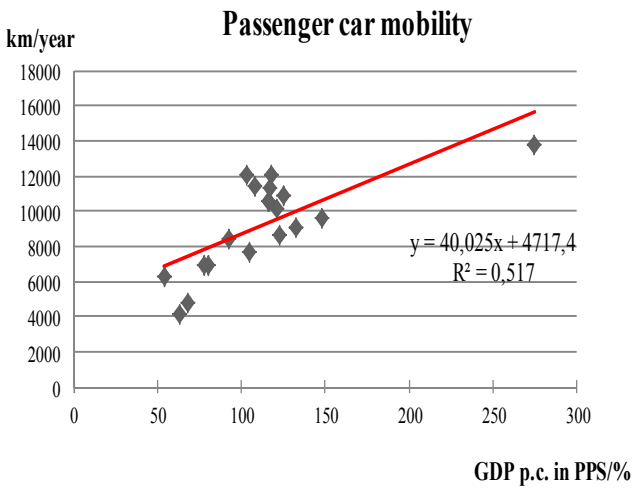

Figure 3: The relation between the GDP per capita and the individual car transport output of the European countries. Source Czech Statistical Office

The graph in Fig. 3 shows that the higher is the GDP, the larger is also the output of the individual car transport, it is interesting that the points mostly left belong to the Czech Republic, Poland, Hungary and Slovakia. On the contrary, the point mostly right represents Luxembourg. So we come to the paradox that the economic freedom leads to the growth of the level of living, but it can have larger impacts on the environment. But does that really hold true? In fact the 20th century brought the crucial question, whether the impacts of human activities on the environment are so serious, that it is necessary to control them by some way. If we consider only the transport, there are at least two evident reasons to make control:

- the ecologic reason – the impacts of transportation on the environment and the human health are continually higher, above all in cities, this is the reason for the higher transport regulation

- the energetic reason – the problems with oil resources and their geographic distribution and above all the security of oil (or natural gas) supply from the countries with less or more dictator regimes lead to the need to seek for new possibilities of car propulsion

The mankind has never been resolving such situation (we do not want to claim, that the mankind did not resolve lots of problems and challenges in its history, only the character of this situation is another). On the one hand the level of living increased markedly in the more advanced (simply said the north one) part of the world, what has surely many reasons; however one of them is the human possibility to use the energy from fossil fuels. But it has impacts on the environment (apart from the greenhouse effect and the global warming like about demonstrable local impacts of the transport on the environment and the human health in cities) and moreover the fossil fuels are exhaustible resources.

IV. Energy and Transport

The world economics has been facing the increase in crude oil and nature gas prices. Nature gas's price increase is usually rather delayed. The primary resources of energy, both, oil and nature gas, represent an essential raw material not only for energy and transport systems, they also have the large deal for the development of other industrial branches. In contrast to the previous crises, we have met certain opinions and predictions about the termination of cheap oil and nature period. The world economics should forget their low prices. It might seem that higher prices signals notify of the lack of oil and nature gas, although this could be false information. The contribution points out at numerous factors influencing the price of the important energy resources. Combined impact of the supply and demand is in question as well as the problem of exhaustion of the above mentioned resources and the competitiveness of alternative resources, geological and geographical conditions, reliability of the supplies and, last but not least, the political, social and terrorist aspects.

Energy remains an important production factor of economic growth. Energy resources must be safe and reliable, environment-friendly and will have to be sufficient for the future. None of the contemporary energy resources is close to any of these conditions.

The demand depends on the following factors: change in industrial structure, material changes and substitutions, transport changes, the development of energy technologies with the higher efficiency. These factors can influence the end energy using in sectors as shown: Civil Engineering (40%), Industry (30%), and Transport (30%). It is supposed that the structure will tend to the higher rate of energy used in transport and still remains based on combustion of fossil fuels. The primary energy resources are crucial for the next decision process. The condition of sustainable development based on a steady growth of primary resources exploitation leads to limited consumption in countries with higher income (energy conservation). Changes in energy production and transformation at a higher efficiency should raise the lower energy consumption in developing countries.

V. Externalities of Transport

Technologic externalities are considered to be one of the causes of market failure. They arise when action of one economic subject (consumer or producer) directly affects the utility of another consumer or the output of another producer without compensation. The utility or production functions are influenced by other factors:

$$u_l = f_l(x_l, x_k), \quad y_h = g_h(v_h, v_k) \tag{1}$$

where

u_l : utility of consumer *l*

x_l : influence of consumer *l* on his own utility

x_k : influence of others on the utility of consumer *l*

y_h : output of producer *h*

v_h : influence of producer *h* on its own output

v_k : influence of others on the output of producer *h*

The negative externalities or external costs are often mentioned in connection with transportation. However it is also important to be concerned with the positive externalities that cause external revenues. Above all we can mention the influence of the transport system on the economic output of a territory. This problems have been studied in economy since the improvement of the GDP measuring thus since the half of the 20th century. They are connected mostly with the name of the American economist Simon Kuznets [2].

The fact often left out in the problems of emissions is the so called Kuznets curve. Simon Kuznets is American economist of Russian origin, who was interested in the measuring of the GDP and its relationships to other quantities. The Kuznets curve tells that the higher is the GDP, the smaller are the social differences (we can see it in the developed states with the strong middle class - many people earn the average wage level).

VI. Environmental Kuznets curve

The derived environmental Kuznets curve (EKC) in not any more his own work, but the construction of the economists Grossman and Krueger [3]. It shows that with the increasing wealth of a country, measured by the GDP, the environment also improves, because for the countries it is profitable to use cleaner technologies only after gaining some level of living. Against this statement the logical objection holds, that countries after gaining certain wealth transfer the production to less developed countries with cheaper labour force. Hence with the production transfer the related emissions are also transferred. But this proposition is not interesting for our research, because we are concerned with the transportation and its outputs can not be transferred elsewhere, they always take place in the given country.

The general shape of the EKC is shown in Fig. 4. Such functions can be modeled by a polynomial of maximum third degree in the linear regression equation

$$z_{it} = \beta_0 + \beta_1 y_{it} + \beta_2 y_{it}^2 + \beta_3 y_{it}^3 + \varepsilon_{it} \qquad (2)$$

with emissions per capita z_{it} in locality *i* at time *t*, coefficients β_i, independent variable average GDP per capita y_{it} and error term ε_{it}.

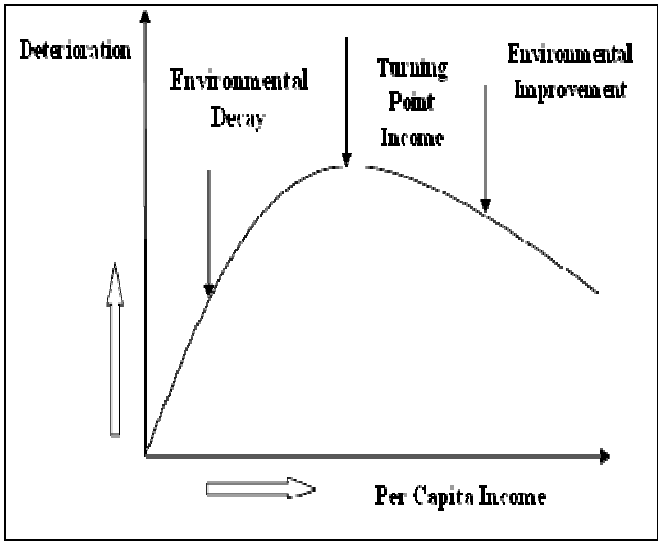

Figure 4: Environmental Kuznets curve. Source [3]

The values of parameters β influence the shape of the EKC according to the following graphs in Fig. 5 and 6.

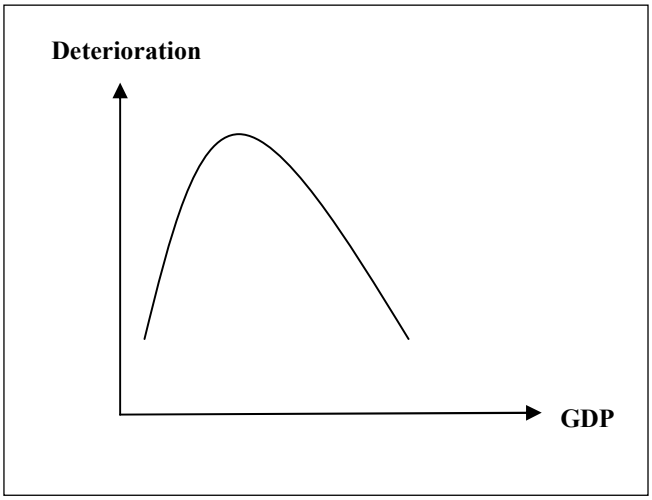

Figure 5: EKC with coefficients $\beta_1>0$, $\beta_2<0$, $\beta_3=0$

If $\beta_3>0$, the EKC can have the shape as shown in Fig. 6. It means that after a phase of decrease the deterioration starts to increase again.

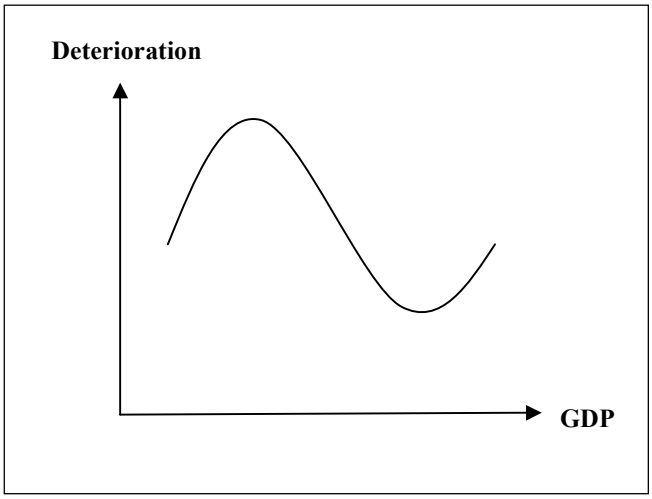

Figure 6: EKC with coefficients $\beta_3>0$, $\beta_2^2>3\beta_1.\beta_3$

Various empirical studies verify the applicability of the EKC [4], but it is necessary to interpret this dependence and to look for the reasons why the environmental deterioration decreases with the economic growth. These reasons can be divided into 5 groups:

- The transition from agricultural character of the society to the industrial one during the industrial revolution was followed by the increased environmental deterioration. This is the explanation of the growing part of the EKC. This development can be today observed in the developing countries like China and India.

- The decreasing shape of the EKC can be explained by technological changes. Innovation has usually been decreasing the energy consumption rate as well as emission factors.

- The demand for better environment has been increasing with the growing wealth. People that had satisfied their basic needs (Maslow's pyramid) have been increasing the pressure on producers to get environmentally cleaner products.

- More wealthy society has been asserting through its public representatives more strict environmental legislation and incentives (of economic character, i. e. consumption and environmental taxes etc.) towards behavior less harming the environment.

- The last reason relates to the transfer of production to poorer countries with lower labor cost, more wealthy countries have been concentrating to the production of services that damage less the environment. This is of course only the case of a local transfer among countries that does not decrease the total environmental damage.

VII. EKC in Road Transport in Czech Republic

The history of the Czech Republic is not so long yet for us to make far-going conclusions. Nevertheless first we tried to show the relation of the emission from transport on the GDP amount (in current prices), what is included in the following graphs, where the carbon dioxide and nitrogen oxides were chosen as emission examples, see Fig. 7 and 8.

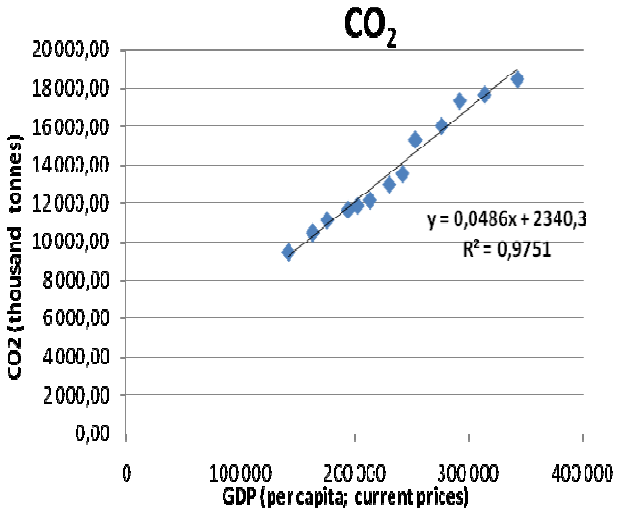

Figure 7:. Road transport CO_2 emissions in the Czech Republic as function of GDP per capita. Source Czech Statistical Office

The performed analysis shows that the Kuznets environmental curve holds true for some types of emissions form transport in the Czech Republic. Definitely we can say that it is not true for the emissions of the carbon dioxide that have been growing dizzily. But its impacts are still controversial and so it is surprising, that many regulations still relate to this type of emissions. It is of course questionable, whether the Kuznets curve must hold true exactly for this type of emissions.

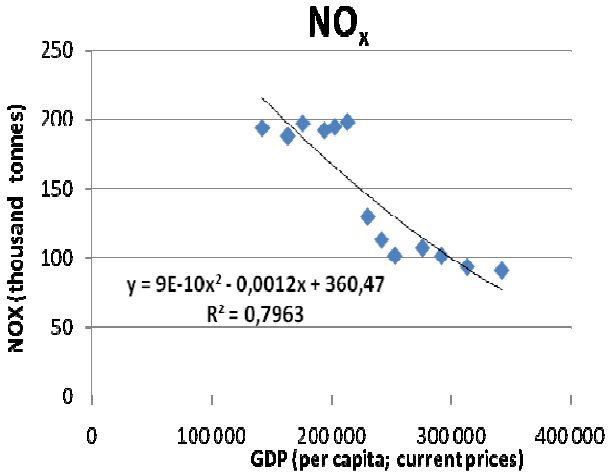

Figure 8:. Road transport NO_x emissions in the Czech Republic as function of GDP per capita. Source Czech Statistical Office

The production of the greenhouse effect with the essential contribution of the carbon dioxide and the factors influencing the carbon dioxide emissions can be expressed in the macroeconomic equation:

$$CO_2 = POP \cdot h \cdot en \cdot eCO_2 \qquad (3)$$

where CO_2 ... amount of carbon dioxide emissions; POP ... population; h ... GDP per capita; en ... energy intensity of the economic system; eCO_2 ... amount of carbon dioxide on the unit of energy carrier (carbon intensity).

It follows from the equation (3), that the emissions grow with the population growth, with the economic growth, with the high energy set out of the economy and with the high portion of the fuels with high carbon content on the produced energy unit. The high content of carbon leads to high carbon dioxide emissions. The population and economic growth will be followed by the growth of emissions.

The emissions can be reduced by:

- the cut down of the energy intensity
- the cut down of the carbon intensity

To decrease the carbon intensity means to move from the fossil fuels to fuels with low or no carbon content.

VIII. EKC in European Road Transport

For the broader verification of the EKC in road transport we have analyzed the emissions as function of the GDP of 16 countries of the European Union (Bulgaria, Czech Republic, Slovakia, Slovenia, Hungary, Estonia, Lithuania, Latvia, Belgium, France, Germany, Netherlands, Portugal, Austria, Sweden and UK). The emissions are averaged (per capita) in population for the purpose of comparison and the use of data from various countries.

Carbon dioxide emissions show in general (regardless the source activity) a strong linear correlation with GDP [5],[6]. Some authors state that the EKC concept may be inappropriate to describe the relationship between economic growth and carbon dioxide emissions [7]. The reason can be that carbon dioxide has been considered as a pollutant recently in connection with the problems of global warming.

In the road transport, the emissions of the carbon dioxide also show an almost linear growth with GDP per capita [8], as shown in Fig. 9.

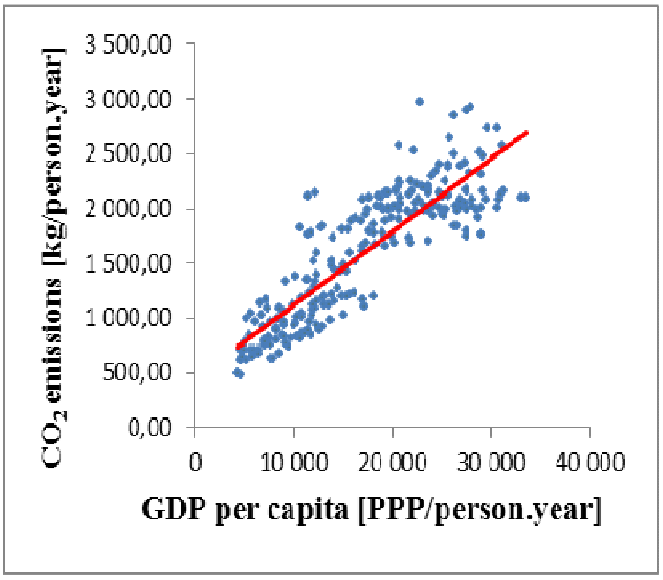

Figure 9: Road transport CO_2 emissions as function of GDP per capita. (Source: Eurostat, own calculations)

The situation of emissions of nitrogen oxides is more interesting. A final regression with a quadratic function was used that corresponds to the theoretical shape of the EKC:

$$z_{it} = \beta_1 y_{it} + \beta_2 y_{it}^2 + \varepsilon_{it} \qquad (4)$$

with yearly NO_x emissions (in kg) per capita z_{it} in country i in year t, coefficients β_i, independent variable average yearly GDP per capita y_{it} (in PPP) and error term ε_{it}. The values of coefficients β_i are

$$\beta_1 = +1{,}32 \cdot 10^{-3},\ \beta_2 = -3{,}34 \cdot 10^{-8}. \qquad (5)$$

Both coefficients are statistically significant at the 5 % level, the regression $r^2=0{,}94$. The graph is shown in Fig. 10.

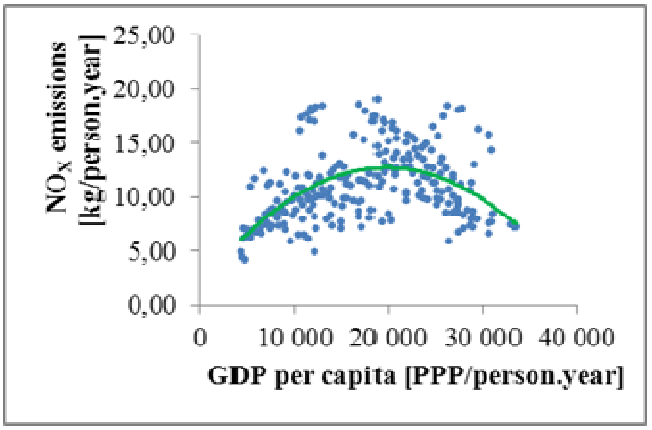

Figure 10: Road transport NO_x emissions as function of GDP per capita. (Source: Eurostat, own calculations)

IX. Energy Consumption in Road Transport

The consumption of energy in road transportation (in the same group of countries) is almost proportional to GDP per capita, as shown in Fig. 11.

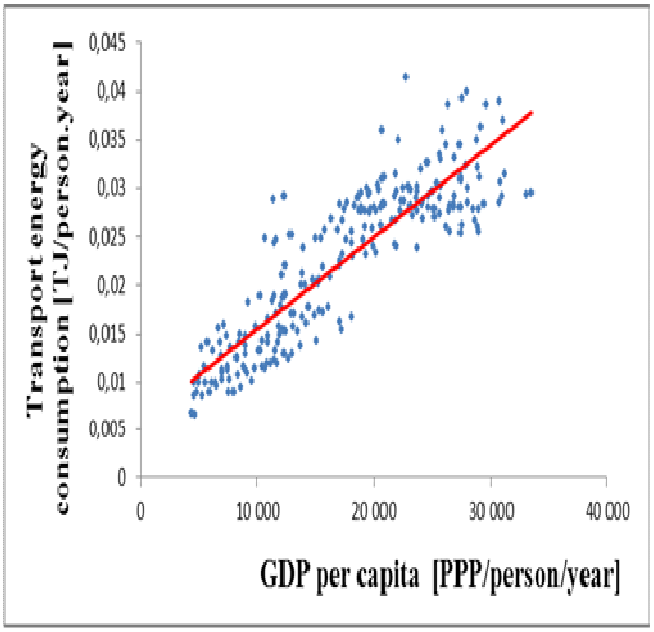

Figure 11: Road transport energy consumption as function of GDP per capita. (Source: Eurostat, own calculations)

The energy consumption (e.g. in road transport) per capita can be expressed as follows:

$$\frac{E}{P} = \frac{E}{Y} \cdot \frac{Y}{P} = \frac{E}{Y} \cdot y = \rho \cdot y \qquad (6)$$

with energy consumption per capita E, population P, GDP Y, GDP per capita y and road transport energy intensity of GDP ρ.

It means that the proportion of energy consumption in road transport to GDP (road transport energy intensity of GDP ρ) is almost constant. The emissions per capita can be then expressed as follows:

$$\frac{X}{P} = \frac{X}{E} \cdot \frac{E}{P} = e \cdot \rho \cdot y \qquad (7)$$

with total emissions X, population P, road transport energy consumption E, emission factor of transport energy consumption e, road transport energy intensity of GDP ρ, and GDP per capita y.

Thus we must conclude that the decrease of emissions per capita can be explained only by the decrease of emission factors that means mainly by the more strict emission standards for vehicle producers (EURO 1–6) and emission controls of vehicles. So other relevant important factors as vehicles with lower fuels consumption rates, better logistics and transport technologies etc. are probably not to contribute at the total to this decrease, because the road transport energy intensity of GDP seems to be constant.

X. Conclusion

The main goal of this paper was to show the importance of the transport for the mankind with respect to its negative externalities in form e.g. emissions. The transportation has an important influence all on the economy and on the generation of the national wealth. As the best example we can mention the industrial revolution, that by supplying unthougt production possibilities forced at the same time the higher efficiency of the transport system (as for the transport means, transport infrastructure or the use of other energy resources). The transportation system strongly influences the economy, the environment as well as the human life quality. The economy with high level of labor division requires an efficient logistics and transport system, but it needs increasing transport capacity and impacts more the environment and energetics of the country. It is a proved fact, that countries with more liberal economy are economically stronger (the relation between the index of economic freedom and the gross domestic product).

The presented data from the Czech Republic as well from some European countries show that for carbon dioxide the environmental Kuznets curve is not valid. But in the case of the emissions of nitrogen oxides (and some other pollutants), our findings are that their emissions per capita from road transport decrease with the growing wealth of society (expressedy by the GDP per capita), i.e. the environmental Kuznets curve could be valid for these type of emissions from road transport. According to our simple analysis the explanation could be only the successful control of emissions, e.g. by the EURO standards and (regular compulsory) emission controls of vehicles. Other important factors like lower consumption vehicles, better transport technologies etc. seem not to contribute at the total to this decrease, because the road transport energy intensity of GDP seems to be constant.

The possible decrease of some types of road transport emissions can be seen as indirect positive external effect of the economic growth. However these positive pecuniary external effects of transport shall be also studied in a more detailed way, what could be the subject of the following research.

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