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Solving transportation externalities, economic approaches, and their risks

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Abstract: The impact of human activity on the environment is an ongoing concern not only in the natural sciences but also in economics. Special attention is focused on the transport system, which is one of the largest producers of so-called externalities. However, its regulation may mean a serious disruption of global logistics links, which are crucial for maintaining international and national trade, gross domestic product formation and, therefore, to maintain the economic level to which mankind is accustomed to and which brings a quality of human life that is the highest in the human history. The article, therefore, examines possible economic approaches and theories to the problem of the relationship between human activity and the environment and the possible reduction of negative externalities. Typical approaches to dealing with externalities include the theories of the English economist Arthur Pigou, who proposed the application of various taxes and subsidies to limit the so-called social costs, whereas the extreme solution is the explicit prohibition of certain activities. In contrast to this approach is the theory known as the environmental Kuznets curve, which states the relationship between environmental damage and the economic performance of a given geographical area. It must be respected that the reduction of negative externalities, or their so-called internalisation, cannot be expected to be a trivial solution. The application of additional taxes or subsidies can lead to many unintended consequences, which may ultimately have a greater negative economic impact than the externalities themselves. Therefore, the conclusion of this article is devoted to a discussion of the potential risks of such regulatory interventions from the government position.

Keywords: externalities, internalisation of externalities, transportation system, environmental Kuznets curve, Pigouvian tax, gross domestic product, environment

1 Introduction

An economic system with a high degree of division of labour would not be sufficiently efficient without well-functioning transport systems [1]. However, this requires ever greater transport capacity and causes greater environmental and energy impacts. The close relationship between transport and the economy can be traced in many examples over the centuries of human existence. In addition, especially since the beginning of the twentieth century, we can observe two sets of problems caused by transport:

- Ecological – the impact of transport on the environment and the health of the population is increasing, especially in cities, which is the reason for increased regulation of transport.
- Energetic – the high energy demands of the transport system, the problems of oil supplies and their geographical distribution and, above all, the security of oil (or gas) supplies from countries with unstable political regimes.

The transport system has a strong link to the resulting quality of life [2]. This is determined by the internal quality of the transport system, standard parameters such as punctuality, comfort, and safety, and its external quality, which is understood as the environmental impacts of transport [3]. The environmental impacts of transport are studied by the theory of externalities, which divides them into negative (noise, emissions, and congestion) and positive, especially the promotion of trade (transport makes the very existence of trade possible), which is a key factor in increasing the economic performance (expressed by the

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gross domestic product [GDP] indicator) of individual countries. The key factor is GDP, which is determined by the level of the transport system (i.e. the level of mobility of freight and passenger transport), but at the same time, its growth enables the introduction of innovations that have lower environmental impact – see Figure 1.

The importance of transport for the economic development of society [4] can be summarised in the following points:

- contribution to GDP formation,
- employment support (production of transport vehicles, construction, maintenance, and reconstruction of the transport infrastructure of the petrochemical industry and the link to other corporate activities),
- trade promotion,
- transport itself (technological output in the form of movement of people and goods),
- mobility in passenger transport, time savings for the population, and
- contribution to the state budget (tax system and wide range of taxes).

1.1 Externalities definition

One of the problem areas, which the economics of the environment deals with, is the questions of external externalities of human activity, external costs, and their internalisation into costs of pollution. The problem of externalities in transport has more special characteristics as, for example, the question of public possessions, possibility of the emergence of conflict of interest groups, considerable political and social function of external costs or transport, etc. Many issues are general – for example, the difficulties connected with monetary quantification of interdisciplinarity of this problem (externalities can be hardly solved from the standpoint of contemporary knowledge of economics as it causes damage particularly in other fields of human activities than transport itself – for example, health care, living, etc.) [5].

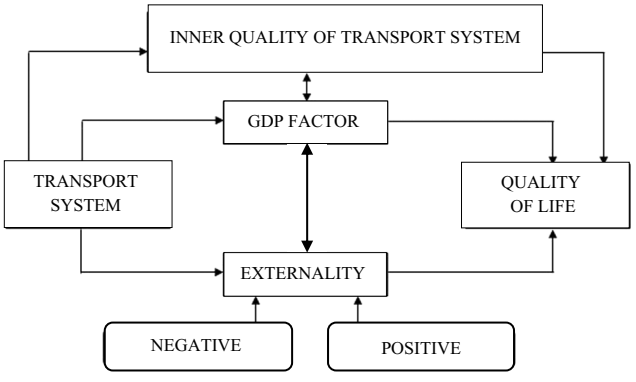

Figure 1: Transport system and quality of life.

Externalities in transport are then investigated with the aim to internalise external costs into the cost of their originator [6]. If we had to keep the principle "User pays" strictly, the internalisation of externalities would fundamentally impact most inhabitants (the increase would influence road transport – bus, individual transport and freight, as well as railway transport, which is more considerate towards the environment but where the capital demand on infrastructure and external costs due to its maintenance and face-lifting is a big problem [7,8]. If we consider that railway and road traffic is a source of employment for about 300 thousand inhabitants in the Czech Republic and that about 3 million people use individual car transport, it will not be politically easy to put through an increase in prices in transport, which would project into operating costs and further into tariff prices, fare, or fuels regarding international competitiveness of the Czech Republic as well.

Then the aim of this internalisation is the influence on the distribution of proportions of the transport system or on the change of transportation shares that are currently displayed by two fundamental fields of the transport system of the Czech Republic – road and railway transport [9,10]. It is a question of how a possible price adjustment can change this rate regarding the fact that it is the only factor out of many that influences the decision making of a passenger or transporter when choosing means of transport [11]. At least we speak about the necessity to integrate the information on its influence on the environment and infrastructure into the price of transportation [12]. Nevertheless, the question of how to carry out this internalisation remains, and two subquestions are derived from this:

- how high the internalisation should be carried out. Then the problem of externalities cannot be only narrowed on their finance quantification, but it is also necessary to perceive their relations to a political environment, which decides on the internalisation. Here, undoubtedly the conflict of particular interests appears. Another problem is how the conflict of interests can influence the process of internalisation of externalities, which is, however, more a case of political (or social) choice than an economic question. Finally, it depends on political representation whose representatives have to be observed from the standpoint of the theory of public choice as persons whose aim – as the aim of every

economic unit – is to maximise their own benefit if it introduces such measures.
- by what kind of taxes to carry out the internalisation, if the problem of consumer tax and its further distribution within the framework of the national budget and the possibility to introduce the so-called purpose taxes (by the term purpose tax we understand such a tax, whose yield is expediently tied to financing concrete public goods or services. It is such a kind of tax that carries information on the way of its further use in it) in transport seems to be topical. Transport infrastructure or public transport are considered public goods and are financed from public funds. However, it is interesting to compare the properties of these goods with the properties by which the public goods are defined as standard ones.

2 Material and methods

Generally, the externalities arise in the case when the property rights are not properly qualified and exacted; in other words, they appear at the moment when particular agents consume certain utility goods together without properly concluded agreements on price and quality when utility functions of a consumer and production functions of a producer are not only influenced by direct participants in production and consumption processes but also by other participants and factors of economic and social processes as expressed by these functions:

$$y_h = g_h(v_h, v_k) \quad (1)$$

$$x_l = f_l(u_l, u_k) \quad (2)$$

where u_l is the benefit of consumer l, x_l is the influence of consumer 1 on its own benefit, x_k is the influence of other participants on the benefit of a consumer, y_h is the output of producer h, v_h is the influence of producer h on his own output, and v_k is the influence of other participants on producer's output.

The basic division is on positive and negative externalities. Positive externalities are external economies; that is, they increase production or benefit for such externalities, which are influenced by the externality. Negative externalities, however, decrease benefit of the other part and mean a negative external economy. As an example, we can mention frequent forms of pollution of the environment. Externalities can be further sorted according to the way of their origin as pecuniary and technological. Pecuniary externalities arise due to mutual interaction of economic activities within the national economy and work via changes of price relations and do not disturb allocation market function. Technological externalities, which arise through the mediation of specific features of concrete activities, are problematic. They do not work through the price system while they spoil activities and production and utility functions of other subjects. Externalities are divided into partial (influencing a limited number of subjects) and global (of the impact on a big number of subjects) or into mono-dimensional (an externality works in the same field where it origins) and multi-dimensional ones. Generally, we can say that externalities influencing the environment belong among multi-dimensional externalities.

From the point of view of the external costs solution, two factors are important – the first one is unambiguously the delimitation of property rights, and the second is the volume of transaction costs connected with the proper solution. The necessary part of property rights is the option to treat our own property freely and the possibility to enforce the rights connected with the ownership. Moreover, transaction costs can be defined as costs of price system or costs connected with a change of property rights. The theory of transaction costs has been often neglected; however, it is of key importance to understand the economic processes [13]. We can say that if we proceeded on the unreal assumption of zero transaction costs, the market system would allocate sources with maximum efficiency. Regarding transaction costs, many of them will not be carried out as in many cases the costs of searching for the counterparty of the change will be too high [14].

Within economic science, the question of the relationship between human activity and the environment has been addressed since about the middle of the twentieth century and is associated in particular with the economist Arthur Cecil Piga. He was the first to define the so-called social costs, that is, externalities, or external costs that are not paid by their originator. Pigou proposed that externalities should be addressed by taxation (i.e. by adding the external costs to the internal costs of the producers of the externalities), but the issue itself is not so trivial [15]. The pitfalls can be summarised as follows:
- internalisation of externalities may bring so-called opportunity costs, that is, foregone revenues from activities that will not be realised due to higher taxation,
- the effectiveness of internalisation of externalities using Pigou taxes depends strongly on the elasticity of demand (e.g. for individual transport) and if demand is inelastic, the internalisation effect will be weak [16,17],
- internalisation may reduce the competitiveness of the economy and undermine economic growth and, as a consequence, paradoxically reduce state budget revenues,

- a non-negligible factor in the internalisation of externalities is transaction costs, which in the case of transport leads to internalisation being addressed by state intervention, but this also raises additional transaction costs.

2.1 Externalities and environmental Kuznets curve (EKC)

The gradual development of econometric and statistical methods led to the refinement of GDP measurement methods in the twentieth century. Perhaps, the most important moment was the economic crisis in the 1930s, which, on the one hand, motivated economists to look for ways to solve or prevent such economic conditions; on the other hand, there was an attempt to define a single unambiguous indicator of economic performance for given territorial units. Although the first group of economists was led by the Englishman John Maynard Keynes, the key figure of the second group was Simon Kuznets, a Belarusian of Jewish origin who had spent his active life in the United States of America. To address these issues today, it is necessary to shed some light on the origin of the GDP indicator itself. Let us return to the figure of the economist Simon Kuznets. In the 1930s, he worked on the creation of systems of national accounts and tried to determine the GDP for the United States of America, which he did retrospectively until 1869. Far more important, however, was the creation of national accounts, whose system gradually allowed countries to collect data and then determine GDP and its structure, or to compare countries with each other according to their economic performance. The methodology of national accounts subsequently spread to the developed countries after the Second World War. However, Kuznets already pointed out that GDP is not a synonym for welfare. The indicator itself includes measurable variables, most famously household and business consumption, government spending and net exports. However, it cannot measure all sorts of economic activities that do not pass through the accounting system. These are, for example, domestic work or the informal economy, something that creates some value but is very difficult to measure. The opposite example would be environmental costs, which should be counted in GDP with a negative figure. Of course, this does not happen; on the contrary, if the costs of repairing these damages are incurred, GDP will increase by them. Finally, Simon Kuznets won the Nobel Prize in economics in 1971 for his "empirically based interpretation of economic growth, leading to a new and deeper understanding of economic and social structures and processes of development". One of the topics Kuznets addressed is the issue of the relationship between GDP development and income inequality [18]. The result is then a relationship called the Kuznets curve. This says that the creation of a middle class (i.e. the levelling of income inequalities in society) only occurs from a certain level of GDP upwards. A strong middle class can thus also be seen as one of the main characteristics of economically developed countries. Income inequality is expressed by the Gini coefficient, based on the so-called Lorenz curve, given by:

$$\text{Gini index} = \frac{\text{area } B}{\text{area } A + \text{area } B} \tag{3}$$

The Lorenz curve is illustrated in Figure 2. The diagonal, that is, the so-called ideal Lorenz curve, captures a situation where every individual in society has the same income, which is obviously unrealistic. The income distribution will correspond to the actual income distribution curve, which will lie below the ideal Lorentz curve, see Figure 2.

If the Gini coefficient is close to zero, society will move towards absolute equality. Conversely, if it took the value of one, one person in society would get all its income, the others would have nothing. The Kuznets curve shows the relationship between this coefficient and GDP and shows that as living standards rise, the Gini coefficient declines (from a certain point) and income inequality decreases, see Figure 3.

A similar relationship is offered by the so-called EKC, published in the 1990s by Grossman and Krueger [19]. The actual Kuznets curve states that the higher the GDP, the lower the social disparities in society (this can

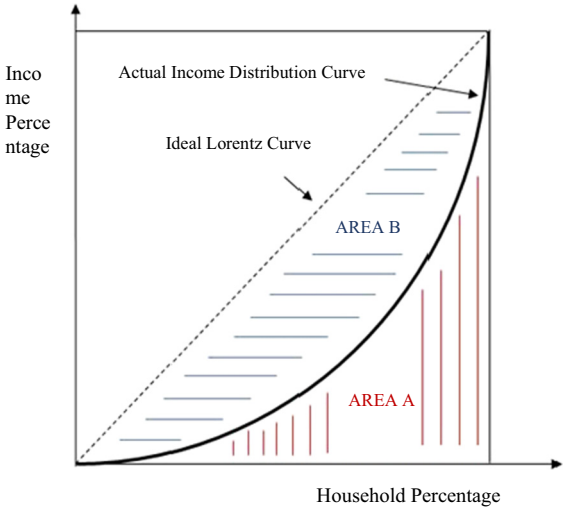

Figure 2: Income distribution in the society.

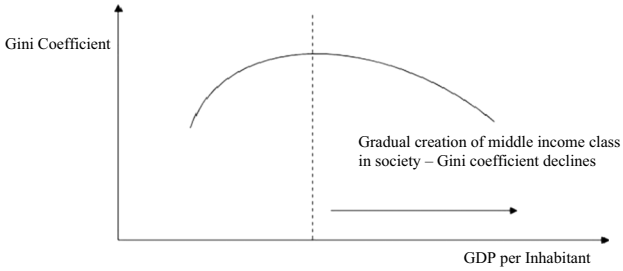

Figure 3: Dependence of Gini coefficient on GDP.

be seen in developed countries where there is a strong middle class – that is, many people reach the average salary level). The derived EKC is no longer his work, but the creation of economists Grossman and Krueger. It says that as a country's wealth, as measured by GDP, increases, the environment improves, because countries find it worthwhile to use cleaner technologies only after a certain standard of living. Both economists sought to extend their research further and came to the belief that improvements occur at GDP levels of around USD 4,000–5,000 per person. Both economists tried to extend their research further and concluded that for most pollutants, the quantity of pollutants does not deteriorate as GDP increases. Grossman and Krueger also gave the EKC a mathematical form, which then reflects the shape of the curve, which can take different forms. The basic mathematical relationship is as follows [19]:

$$Y_{it} = G_{it} \cdot \beta_1 + G_{it}^2 \cdot \beta_2 + G_{it}^3 \cdot \beta_3 + X_{it} \cdot \beta_4 + \varepsilon_{it} \qquad (4)$$

where Y_{it} is the selected pollution type for country i in year t, G_{it} GDP converted to purchasing power parity per capita for country i and year t (unit of currency/person, year), X_{it} is the parameter that captures other variables with an impact on pollution (energy consumption, population, density, etc.), β is the parameter of the resulting shape function, and ε_{it} is the error parameter.

This relationship and the empirical investigations that follow suggest a possible pattern of the relationship between GDP and environmental damage, which will be further illustrated with specific statistics. The basic two variants of the values of the β coefficients are shown in Figure 4. In addition to the basic shape of the function (inverted U-shape), there is also the possibility that the EKC does not have an increasing trend again after a certain decrease in emissions (the shape of the curve would then resemble the letter N) [20]. As already mentioned, the values of β will affect the resulting shape of the EKC. In the case that $\beta 1$, $\beta 2$, and $\beta 3$ take non-zero values and at the same time $\beta 2$ reaches a negative value, this means that after a phase of decreasing pollution, there will be an increase again. One of the main objectives is to investigate the GDP levels at which these changes occur. Mathematically, the maximum (the level of GDP at which the turning point occurs) can be expressed in terms of the first derivative, which for variant A, where pollution increases again after the decline phase, is expressed as follows:

$$\frac{dY_{it}}{dG} = \beta_1 + 2 \cdot G_{it} \cdot \beta_2 + 3 \cdot G_{it}^2 \cdot \beta_3 = 0 \qquad (5)$$

or

$$\beta_1 + G_{it} \cdot (2 \cdot \beta_2 + G_{it} \cdot \beta_3) = 0 \qquad (6)$$

Similarly, in the case of a single peak (inverted U-curve, where $\beta 1 < 0$; $\beta 2 > 0$, and $\beta 3 = 0$), the derivative will be as follows:

$$\frac{dY_{it}}{dG} = -\beta_1 + 2 \cdot G_{it} \cdot \beta_2 = 0 \qquad (7)$$

resp.:

$$G_{it,opt} = \frac{\beta_1}{2 \cdot \beta_2} \qquad (8)$$

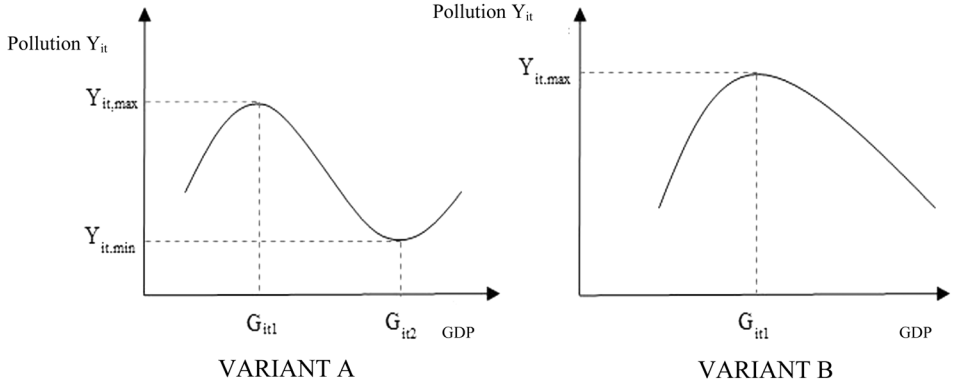

Figure 4: Possible shapes of the EKC.

3 Results

3.1 Possible interpretations of the EKC

Various empirical studies confirm the validity of the EKC, but it is necessary to further explore the interpretation of this relationship and to find reasons why the environmental impact is gradually decreasing with GDP growth. These reasons can be divided into five groups:

- the transition from an agricultural to an industrial society during the industrial revolution meant, first of all, an increased burden on the environment (it is necessary to mention that cities did not offer any idyllic environment before the industrial revolution). From this point of view, the first half of the Kuznets curve is, therefore, logical; the start of industrial activity also means more emissions, noise, and other burdens (transport is also linked to the start of industrial activity). This is how we can look at developing countries in Africa or Asia (China, India) today, which are going through a period of high economic growth with significant and increasing environmental impacts [21],
- the shape of the EKC also results from the evolution of another variable, which is technological changes. If we call technological changes a "variable," it is necessary to add that its evolution is difficult to predict, but knowledge of history shows that technological changes (in production or transport) probably occur and lead to a reduction in unit energy intensity. In this context, it can be added that the reduction of fuel consumption in cars should be given the same attention as the development of new alternative fuels and propulsion systems,
- along with rising living standards, the demand for a better quality of life is also increasing. As people can meet their basic needs (according to Maslow's pyramid), pressure on producers to produce more environmentally friendly products increases. In economic terms, this pattern can be formulated as the elasticity of demand for consumer goods decreases with growing wealth, whereas the elasticity of demand for goods that indirectly affect quality of life, such as clean air or a noise-free environment, increases [22],
- at the same time, the richer society, through its public representatives, promotes the adoption of stricter environmental standards or incentives (which are economic in nature, that is, consumption and environmental taxes, various fines, etc.) towards behaviour that is less damaging to the living environment. These incentives can of course be a problem for the national economy if they raise costs for producers and make the economy less competitive, as may be the case with environmental taxes aimed at reducing CO_2 emissions,
- the last group of reasons is related to the shift of production to poorer countries, which have a labour force with lower wage costs, whereas richer countries concentrate on the production of services, which is much more favourable in terms of environmental damage. In this context, some authors have pointed out that the overall effect is not a reduction but merely a transfer of environmental impacts between countries.

To verify the validity of the EKC in road transport, it was necessary to analyse the evolution of emissions for 16 countries of the European Union 3, whereas the results vary for different types of emissions [23]. The countries were selected to cover the full range of GDP levels in purchasing power parity (in EUR/person units). Countries will be further subdivided for the purposes of the study into groups according to the average level of GDP per person in public private partnership terms. For the assessment of the EKC for CO_2, countries are divided into two:

- countries with a higher level of GDP, which averages EUR 24,269 per person per year, which includes Belgium, France, Germany, the Netherlands, Portugal, Austria, Sweden, and the UK,
- countries with a lower level of GDP, with an average of EUR 12,420 per person per year, which includes Bulgaria, Czech Republic, Slovakia, Slovenia, Hungary, Estonia, Lithuania, and Latvia.

For the assessment of the EKC for nitrogen oxides, countries are divided into three groups:

- countries with a higher level of GDP, with an average of EUR 25,424 per person per year, which includes Austria, Belgium, France, Germany, the Netherlands, Sweden, the UK,
- countries with a medium level of GDP, with an average of EUR 16,518 per person per year, including the Czech Republic, Portugal, and Slovenia,
- countries with a lower level of GDP, with an average of EUR 10,997 per person per year, including Bulgaria, Slovakia, Hungary, Estonia, Lithuania, Latvia

As a first example, the GDP-CO_2 emissions relationship can be presented, where a linear approximation (Figure 6) is performed. This approximation shows that the growth rate of CO_2 emissions as a function of GDP is much faster for countries with lower GDP levels, whereas the growth rate of CO_2 emissions decreases for countries with higher GDP levels. For countries with a GDP level between 5,000 and 20,000 Euros per person per year, the

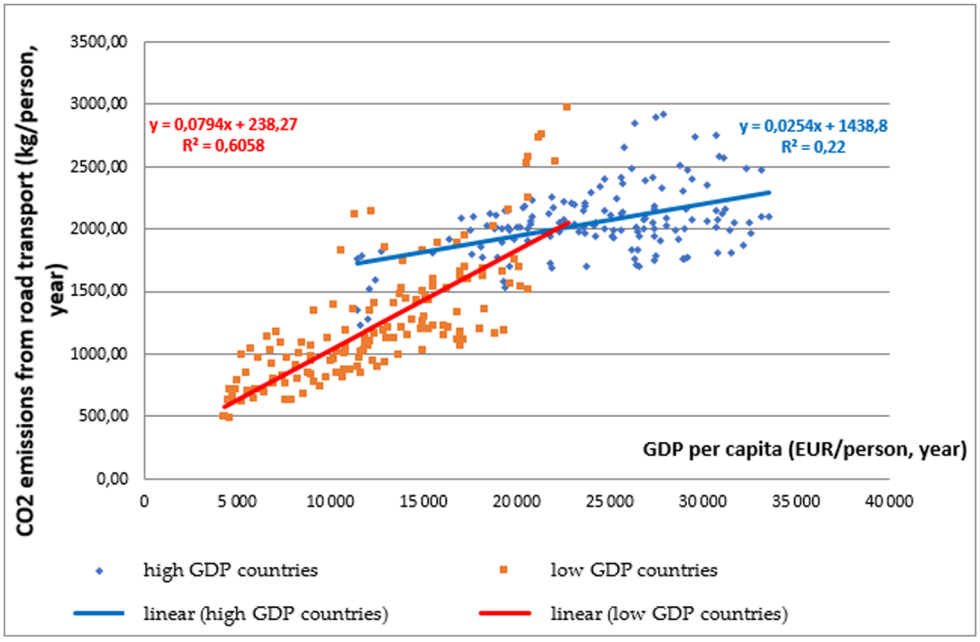

Figure 5: Dependence of CO_2 emissions on GDP – approximation of linear functions, data source: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/; United Nation Framework Convention on Climate Change (UNFCCC), own calculations.

steepest CO_2 emissions are observed, whereas for countries with a higher GDP between 20,000 and 35,000 Euros per person per year, the growth is slower, and for some countries CO_2 emissions even decrease (Germany, UK, France), see Figure 5.

Nitrogen oxides are a major component of ozone (or dry smog). These include nitric oxide NO and nitrogen dioxide (NO_2). They react with water in the atmosphere and contribute to acid rain, whereas nitrogen dioxide reduces resistance to viral diseases, pneumonia, etc. Ozone is mainly formed where nitrogen oxides and volatile organic compounds are present, mainly in areas with heavy traffic (hence the name Los Angeles smog according to its frequent occurrence). For the approximation of nitrogen

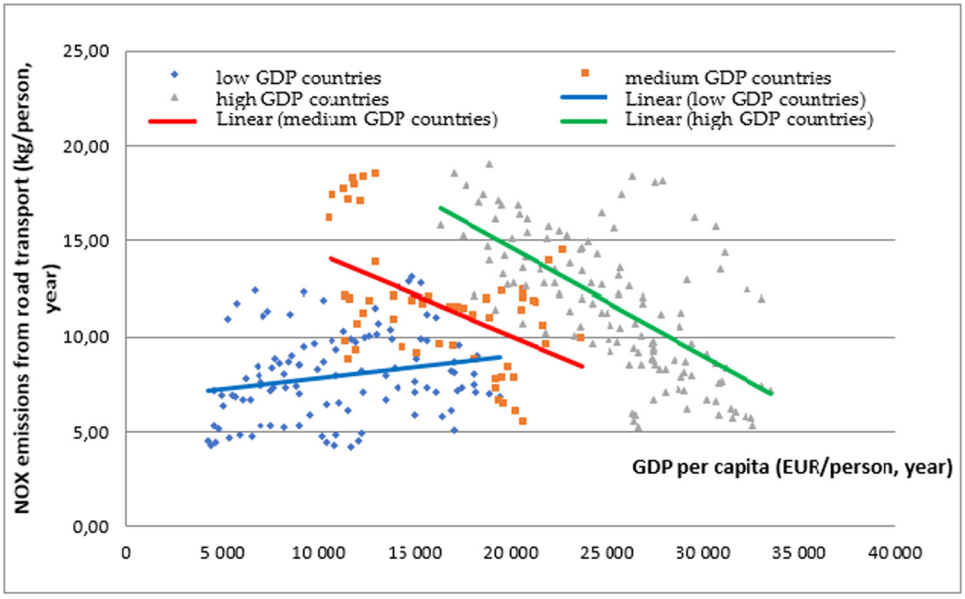

Figure 6: Dependence of NOx emissions from road transport on GDP – linear approximation, data source: http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home/; UNFCCC, own calculations.

oxides from road transport as a function of GDP, countries are divided into three groups and again the approximation is made by a linear function, see Figure 6.

4 Discussion

The development of economic thinking, as in other sciences, depends on the possibilities of measuring individual variables and their statistical detection and records. If the performance of economics has been measured through GDP for about a century (when one of the main reasons was the economic depression of the 1930s), it is only logical that the impact of this indicator on various quality-of-life factors, including the impact of human activity on the environment, has been investigated.

If, except for CO_2 emissions, we can observe an inverse correlation with GDP in road transport statistics, it can be assumed that this is mainly due to the increasingly enforced standards (EURO I–EURO VI). However, the ability to incorporate these standards into economic life is also highly dependent on the economic strength of society, that is, whether it is able and willing to bear the costs of introducing new environmental standards. Understandably, in the second wave, we must see the cause in technological innovation – the ability to design vehicles with lower fuel consumption and therefore lower specific emissions of pollutants [24].

In the context of road transport, there is mostly talk of negative externalities, which is undoubtedly necessary, but there is very little discussion of positive externalities, the contribution of transport to economic growth (and therefore positive externalities of GDP growth), despite the fact that this is an indirect effect of transport. Any measures to reduce negative externalities should not lead to a possible reduction in economic growth, which itself can be a source of positive externalities and can prevent the negative ones [25].

The economists whose studies are also mentioned in this article and who were concerned with the ways of measuring the economic performance of society, especially in the post-World War II era, also came up with comparisons between economic performance and various qualitative factors of society. The first of these was the so-called Kuznets curve, which at the end of the twentieth century was extended to other areas than the initially so-called social (income) inequality. Probably, the most famous application of the curve is in the field of the relationship between the economy and the environment. As far as countries with higher GDP are concerned, it is possible to observe a decrease in the rate of growth of CO_2 emissions from road transport compared to countries with lower GDP. Statistics show that in richer countries the motorization rate is growing very slowly or not at all, and it is more likely that there is a renewal of the vehicle fleet with the assumption that these are more efficient means of transport in terms of emissions. This may ultimately be the reason for the declining emissions in countries with higher GDP.

5 Conclusion

The EKC theory itself is very young – scientists have been addressing it for about three decades. Its key idea is the contradiction between different views on how to deal with the external costs of transport. It turns out that if GDP growth alone leads to a reduction in external costs, the introduction of various tax and subsidy measures – based on the so-called Pigouvian approach – is a concept that should be approached with the utmost caution. This relates to the relationship between the transport system and externalities, or rather to their resolution through Pigouvian taxes. Not even in this respect is the situation is not entirely clear-cut either. If the basic thesis speaks of the need to internalise negative externalities, there are two circumstances that need to be considered at the same time:

- Internalisation alone does not necessarily lead to the desired effect considering the inelastic demand for individual transport,
- at the same time, such internalisation must not lead to a reduction in economic output as measured by GDP and thus to a reduction in the positive effects of this growth.

A significant risk of increasingly stringent measures to reduce greenhouse gas production may be deeper and very difficult to predict social distortions. These can be characterised as follows:

- Rising prices for energy raw materials, electricity, and fuels, inter alia because of the introduction of carbon taxes or the impact of emission allowances,
- reduced mobility and the resulting restriction of material flows and population movements, with the logical consequence of reducing the productivity of the economic system,
- loss of competitiveness of companies, shifting production to other areas in the world,
- a reduction in the economic performance and living standards of the population, which will be associated

with other societal consequences that are difficult to predict,
- pressure on public budgets, rising public debts, the associated rise in the price level, that is, inflation, and possibly other macroeconomic imbalances.

Another area of concern is energy utilisation in transport. If we talk about the gradual replacement of fossil fuels by other alternatives, the following remarks must always be considered (Duchoň B., Transport, Economic Growth, Region, Utility):
- it is crucial to monitor price developments, especially on the crude oil market, or on markets for other energy commodities such as natural gas,
- for alternative fuels, it will also be crucial to consider possible price changes due to increased demand,
- it is unclear how environmental changes that may be influenced by the use of fossil fuels as a primary energy source will continue to evolve,
- the possible substitution of fossil fuels in transport is still problematic, particularly regarding the qualitative characteristics of possible substitutes and their limited ability to replace fossil fuels in transport on a mass scale, and
- security risk and security of supply issues will also be crucial, given the geographical distribution of energy raw materials in the light of current geopolitical world development.

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