Highway Infrastructure and Economic Growth

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Abstract

Transport infrastructure is essential for economic growth since it is connected to a large number of economic activities. The importance of road infrastructure in Europe is increasing as almost half of the freight transport in the European Union is done by road. Studies about the connection between the expansion of the highway network in particular and economic development have been elusive. The purpose of this paper is to examine in more detail the relationship between highways construction and economic growth. In order to do that, a panel data for 21 European countries over a period of 12 years is used. The results of the applied instrumental variable approach show that development of the highway infrastructure has a significant positive impact on economic growth. Furthermore, a conducted Granger causality test shows that highway infrastructure causes long-term economic growth in terms of GDP per capita growth. These findings underline the importance of continuous development of the road infrastructure and prove that governments should implement policies that additionally stimulate economic growth through infrastructure development.
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Introduction

Transportation has always been essential for international trade and countries’ development. In the past, the most important mode of transportation was the sea transport. Goods from all around the world were transported by sea to harbours in big cities in coastal regions. Transportation by land was difficult because of bad or even non-existing infrastructure. It was also unsafe, since merchants and traders were frequently attacked and robbed while traveling from one place to another. Later on, the massive advantage of rail transport was recognized and utilized by the subsequent development of the railroad infrastructure. This allowed for intraregional trade and transportation by land, which significantly affected economic development. Eventually, due to its largely unlimited accessibility and flexibility, road transport became the major mode of transportation. According to the European Commission, goods that are transported by road account for 45.3% of all freight transport in the European Union (European Commission, 2013). It is therefore important to understand that changes in the road infrastructure can, to a very large degree, affect the economic situation in a country. Improvements of the infrastructure facilitate road transportation, allowing for larger volumes of transported goods, shorter transport times and increased efficiency of the logistics and haulage industries. Since infrastructure appears to be important for the economic state of a country, perhaps it has something to do with the economic growth levels.

During the last couple of centuries the world is experiencing a noticeable uptrend of economic development. This global development has been largely influenced by the advance in technology. The progress, achieved by telecommunications, the improvements in production technology and the use of more efficient production processes has created suitable conditions for sustainable economic growth and development. Nevertheless, growth and development are not equal around the world. Some regions develop in bigger steps than other. The difference in growth levels can perhaps be explained by different geo-political history, different resource endowment, human capital, labour productivity, and technological progress. Even then, there are many economic factors that also affect the level of economic stability and the growth rate at which the economy is expanding. Despite this, not all the factors that influence the GDP of a country are investigated equally. It is more common that economists focus on inflation, labour productivity, international trade, foreign direct investments or government policies to determine the behaviour of the economic output. On the other hand, factors like infrastructure, and more particularly transport infrastructure, receive fewer spotlights.

Since transport infrastructure is more or less connected to almost all aspects of the economy, this paper will try to present more clearly its impact on economic growth and development, focusing mainly on road transportation. Highways connect the major cities in a country and provide fast routes for road transportation. Moreover, they can take on large amounts of vehicles and thus ease congestions on smaller roads. This means that the highways are in fact very important for this mode of transport. The size of this impact is not clear and deserves more attention. Therefore, the purpose of this paper is to find an answer to the question how development of highway infrastructure influences economic growth. This question will be answered by doing a panel data regression analysis, which includes 21 European countries over a period of 12 years (2001-2012). The analysis should help understand the nature of the relationship that exists between these two variables.

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1 List of the countries, used in this paper is provided in the Appendix.
addition, a causality test will be done to further clarify the importance of development of the highway infrastructure.

Shedding light on the relationship between road infrastructure and economic growth could help the development of better government policies that take into consideration the importance of roads and the transportation infrastructure in general for sustainable economic growth and development. A different attitude towards the highway network could significantly increase the possibilities for development of the countries that manage to fully utilize the potential benefits of efficiently working highway system.

The remainder of this paper has the following structure: section 2 describes the main theories about the connection between infrastructure and economic growth, while in section 3 a brief literature review is done on previous studies on this topic. Section 4 deals with the methodology of the paper. It explains the model to be tested and the variables that are used. Section 5 describes the data that is used in this paper and the necessary changes done to it. The results from this study are presented and discussed in section 6. Section 7 deals with the Granger causality test to examine the causal relationship between highway infrastructure growth and GDP per capita growth. Finally, the conclusions of this paper are stated in section 8, together with some ideas for future studies of this topic.
2 Theoretical background

This section provides the theoretical framework, which connects infrastructure to economic growth. It furthermore clarifies the importance of infrastructure and transportation to the economy.

2.1 Linking Solow to infrastructure

Lucas (1988) states that once someone starts thinking about economic growth rates, it is very difficult to think about anything else. Growth has always been the main field of research in economics and has been present to some extent in almost all research studies. Different standards of living between countries, different resource endowments, asymmetrical trade and disparities of income in various countries have led to the creation of many economic models and theories that try to explain these discrepancies. Moreover, these models try to determine if there are any ways to increase the rate of economic development and improve welfare. One of the most popular and common economic growth models is the Solow-Swan model. This model states that the pure accumulation of physical capital is not enough to explain the large growth that some countries are experiencing over time, or the big differences in output per capita in different regions. The main conclusion of the Solow-Swan model is that sustainable growth over time is possible only through an increase in labour productivity (Romer, 2012). Increase in the productivity levels can be accomplished by an increase in the effectiveness of the labour, achieved often by technological progress. The Solow-Swan model treats technological progress as exogenous and puts it forward as the only possible explanation of long-term growth.

The rate of development in technology can be attributed to several different factors such as investments in technology, knowledge spillovers, human capital and public infrastructure (Mastromarco and Zago, 2012). Better infrastructure can contribute to the technological progress and its determinants. Additionally, Bougheas et al. (1997) consider infrastructure to be a cost-reducing technology by itself, therefore arguing that technological progress in the form of infrastructure development leads to reduction in the cost of production. In turn, lower cost means increased competitiveness of the firms and more benefits for the country in international trade. Furthermore, technological progress is supported by infrastructure development, since it provides more opportunities for establishing connections between different cities, regions or countries, thus enhancing the ability to move production factors and facilitate the migration of human capital. Hence, infrastructure helps for the increased gain of knowledge spillovers, one of the main drivers of technological progress, and also proves important for the information and technology flows between different points in space.

2.2 Infrastructure and economic geography

In the past decades, researchers in the field of economics recognized a distinct area of the economic science which has been overshadowed by the main theoretical models and interpretations, namely economic geography. Initially explained by Krugman as “the location of production in space” (Krugman, 1991:1), it has grown to become one of the main pillars of the new economic theory. Economic geography proved to be important because in the real world economic activity is scattered across space. The dispersion is not equal, however. Population, manufacturing activity, services and markets are concentrated in specific centres of economic activity. This concentration is in fact one of the main points of the economic geography (Krugman, 1991:5).
According to Krugman (1991:10), the concentration of economic activity in certain regions creates increasing returns for the firms that locate in these regions. This is one of the main incentives for firms when they choose where to locate. Moreover, the location choice is also connected to the size of the corresponding market for the firm's products. Here comes the hurdle in making the correct decision. The best place for production and the largest market for the firm are not necessarily in the same place. Therefore, the location decisions of the individual firms are greatly influenced by the existing connections between the production region and the market and the consecutive transport costs that come with that.

There is imminent exchange of goods, knowledge, capital or labour between the different centres of production and consumption. Hence, the connections between these centres, regardless of whether they are at national or international level, are important for the prosperity and economic development of the society. The spatial concentration of manufacturing and the allocation of resources between regions are in the base of international trade – a major field in the economics science. Previous economic theories focus on the national economy, managed by the government or market forces, and the international relations between clearly specified and identified countries as an economic unit. In the last couple of decades, however, national borders became somehow blurred with the establishment of different international unions and trade organizations. In this case, the new economic theory and economic geography much better explain the relationships between different regions and the regional trade flows that occur now on the international level (Krugman, 1991:8).

Focusing on the national market first, each manufacturer prefers to serve the market from a single location, given the right economies of scale and transportation costs (Krugman, 1991:15). Minimizing transportation costs is usually achieved by locating close to the largest market, but every rational manufacturer would want to serve the rest of the country and other markets as well. This underlines the importance of the transport infrastructure and the opportunities it provides for low transportation costs and fast transition times. It is clear that improvements of the infrastructure will allow for increased profits for the firm and increased economic development for the region through the facilitation of trade.

The advantages that are derived from the localization and concentration of the economic activities in a region are enhanced by the transportation infrastructure within the region and the infrastructure that connects it to other regions. A good example of this principle is the United States manufacturing belt in the Northeast part of the country. Its advantage was created and supported by the extensive railroad network that connects the region’s cities (Krugman, 1991:23). Any firm will take into consideration the transport costs to other regions and the fixed costs for establishing at another location. The intensity and development of the infrastructure in one region creates the so-called transportation network effect (Krugman, 1991:25). This means that even in the transportation there are economies of scale. A larger volume of goods that are being transported between different locations will drive down the transportation costs, which in turn will attract more firms to that region. Hence, the transportation network effect is one of the incentives for concentration and the respective transport costs provide the base for that effect. Therefore, reducing the transport costs is essential for the continued development of the region. This reduction can be achieved by improvements of the existing infrastructure, or by its expansion.

Another aspect of localization and concentration explained by Krugman (1991:38) is the labour pooling. This pooling is considered as an individual source of localization and
therefore can significantly influence the location decisions of individual firms. The positive effects and externalities that are associated with labour pooling are a direct consequence of the migration of skilled labour force. This migration can be facilitated by improvements in the transportation infrastructure.

Centralized areas attract more manufacturers and suppliers because of the reduced transport costs between them. Regardless of whether the firms produce intermediate or finished products, they will still choose to locate in these regions – manufacturers of final products want to locate close to their suppliers and the suppliers want to locate close to their customers. On the other hand, even though the transport costs are reduced in localized areas, they are still present. In order to minimize the expenses for transportation, firms choose to locate close to the largest supply of inputs, needed for the production process. Of course this location is also chosen by other firms, which creates concentration. The clustering of suppliers has an immediate effect on the transport costs of intermediate goods. It is often wrongly assumed, however, that such clustering will occur only if the transportation costs are high. Contrary to that, Krugman (1991:50) argues that localization will not occur only if the transportation costs of intermediates are very low. Moreover, according to the author, reduction in transportation costs of both intermediate and finished products will encourage localization. This would have a direct impact on the growth and development of the region, in which the localization occurs. The bottom line here is that transportation infrastructure proves to be fundamental regarding the location decisions of firms, and thus is important for regional development.

2.3 National perspective

In addition to being an important factor for regional development and regional localization, infrastructure is crucial to interregional and international trade. Reduction of transportation costs removes the barriers for international trade (Krugman, 1991:79). Increased trade flows imminently lead to increased welfare of the regions that are trading either through increased exports and revenue, stronger currency or increased competitiveness. If transportation costs become extremely low, location will no longer matter, which will lead to dispersion of economic activity (Krugman, 1991:89). Therefore it is possible to encourage and facilitate development in underdeveloped and fall-back regions by improving the existing transport infrastructure. Reduction in transport costs has two effects. First, low transportation costs allow firms to locate their production where the input factors are the cheapest, thus reducing the production costs. Second, the ability to cheaply transport finished goods to the respective markets enables the location of all manufacturing in one place, which serves all the markets. In this way the firms experience economies of scale (Krugman, 1991:96).

There is an additional viewpoint of the effects of the transportation infrastructure. This viewpoint concerns its accessibility. In some cases this is even more important than the transport costs for goods. Paul Krugman (1991:96) states that firms may locate their production in places where the costs of production are higher, but the access to the transport infrastructure is better. In this line of thought it makes sense for the accessibility to be constantly improved. This could be accomplished by either creating new infrastructure or expanding the existing one. Regardless of the approach, increasing the accessibility requires investments in the infrastructure. In most cases these investments come from the government. Aschauer (1989) shows a direct connection between the public sector and the economic output \(Y = A, * f(N, K, G)\), where Y stands for the output of goods and services, A presents a measure of productivity, N is employment of labour
services, \( K \) symbolizes stock of non-residential capital and \( G \) represents the services from the government sector. The author claims that government spending can be much more important for determining the productivity of the private sector. Furthermore, in terms of public expenditure, Aschauer (1989) argues that core infrastructure, including streets, highways, airports and other, has highly significant impact on growth and productivity improvements. The connection between infrastructure and output growth is also established by Esfahani and Ramirez (2003). The article uses a Cobb-Douglas production function that includes infrastructure assets: \( Y = K^{\alpha}N^{\beta}(QL)^{1-\alpha-\beta} \), where \( Y \) is the aggregate output, \( K \) is non-infrastructure capital, \( N \) represents the infrastructure assets and \( QL \) specifies the productive labour. This function additionally shows the direct connection between infrastructure and economic output.
3 Former studies

This section presents a brief overview of the previous studies regarding infrastructure. It furthermore illustrates the impact that it has on economic activity. Additionally, this chapter explains why road infrastructure is important when it comes to economic growth.

3.1 Infrastructure and growth

As discussed in the theoretical section of this paper, Aschauer (1989) finds significant relationship between public expenditure including infrastructure and economic output and growth. The big impact of infrastructure on productivity is widely discussed in the literature and the results of this study are confirmed by other authors, who arrive at similar conclusions (Munnel and Cook, 1990; Gramlich, 1994; Holtz-Eakin and Schwartz, 1994; Miller and Tsoukis, 2001).

Lynde and Richmond (1993) argue that the effect of public expenditure is even wider and it encompasses the growth increase that is achieved through raise in the productivity levels. The authors examine the UK manufacturing sector and find out that larger rates of infrastructure investment could have led to increase in the labour productivity of around 4%. This subsequently influences the industry growth and economic growth, proving that there is a connection between infrastructure and economic development. This study also strengthens the relationship between infrastructure and productivity of the firms.

Devarajan et al. (1996) partly support the idea that increased public expenditure, including investment in infrastructure development, is responsible for increased economic growth rates. However, the authors also highlight the case when the excessive amount of expenditures makes them unproductive. This is not rarely the case in developing countries, because according to the authors the governments in these countries are misallocating resources. This shows that public expenditure can also have a negative effect on the economy of a country.

Economic output is mainly connected with the firms’ production capabilities. These capabilities can be affected by infrastructure in several ways. First, the inbound and outbound logistics are strongly dependent on the existing infrastructure. Thus, any changes in the current state of the infrastructure imminently affect the economic output. Second, advanced infrastructure allows for production factors to be more mobile and more productive. Due to the aforementioned connections, regions and countries with better infrastructure attract more people and companies and facilitate agglomeration and clustering (Gillen, 1996), which in turn increases economic growth rates.

The institutional and economic characteristics of a country tend to significantly influence the effects that are created by the infrastructure (Esfahani, Ramirez, 2003). Furthermore, the institutional capabilities and the effectiveness of government policy have a great impact on the growth process that is achieved through infrastructure development. The substantial impact of infrastructure on GDP can be further increased by improving the performance of the infrastructure sectors.

A study by Calderon and Serven (2010) shows that the impact of infrastructure on economic growth and development is greater in more developed countries than in developing ones. This could be attributed to the fact that in developing countries the construction of new infrastructure has a local effect. Construction of a new road or highway connects local communities and serves a regional goal. Contrary to that, in developed countries the infrastructure development has a more general, nationwide effect.
A new stretch of highway connects to the existing highway network and facilitates access to all points of that network.

When talking about GDP and economic growth, one must certainly mention the relationship to international trade. As it is considered one of the main determinants of GDP, trade and its associated costs are important aspects of the economic situation in a country. Ajakaiye and Neube (2010) argue that costs for infrastructure services are a large part of trade costs. Since trade costs are an element of the total business costs borne by the companies, the higher the cost of doing business, the lower the economic output is. Hence, Ajakaiye and Neube (2010) state that reduction in trade costs, achieved by a meaningful infrastructure development is a prerogative for sustainable economic growth.

### 3.2 Importance of transport infrastructure

Aschauer (1990) digs deeper into the importance of public spending and more specifically infrastructure. The author claims that infrastructure and its development provide unique economic opportunities, which are achieved through the increased mobility of production factors and better access to markets. The movement of people is included in the mobility of the production factors. Firms can access a larger pool of workers, not necessarily restricted to the surroundings of the firm’s location. Workers can migrate to economic centres that provide more job opportunities and better wages. Furthermore, Aschauer (1990) states that the access to different markets is facilitated by infrastructure development as it reduces transport costs and transition times. The main finding of this paper is that the level of output is significantly and positively related to the investments in transport infrastructure. Moreover, improvements of the infrastructure are believed to lead to improved quality of life.

As mentioned in the theoretical part of this paper, economic growth is sustainable if it is supported by technological progress and productivity growth. Opportunities for productivity growth, as pointed out by Garrison (1996), can be established through improvements of the transportation infrastructure. Thus, development in transportation proves to be of importance for economic growth and development. This statement is supported by other studies, which also find a significant relationship between development in transportation and economic performance. Knight et al. (1993) state, that the expansion of transportation and telecommunications infrastructure is also associated with an increase in the economic efficiency.

The impact of transportation infrastructure on trade is also widely discussed by researchers. Jimenez (1994) claims that infrastructure has a big positive effect on trade. That effect is expressed in the sense that development in infrastructure and its expansion reduce transaction costs. Anderson and van Wincoop (2004) confirm these findings. The authors even add that the government policies about transport infrastructure are more important to trade costs than direct trade policy instruments such as tariffs and quotas. Moreover, they state that transport infrastructure is likely to have a significant considerable effect on the time costs of trade. Hence, a better infrastructure is believed to consequentially improve trade.
3.3 Effects of the infrastructure development

The effects of infrastructure development can be divided in two major categories. The positive effects are considered to be greater than the negative, but there are some controversial effects as well.

One of the potential positive effects of infrastructure development is the reduction in congestion (Aschauer, 1990). It can be achieved by increasing the capacity of the existing infrastructure or by replacing it with a newly constructed one. Reduced congestion could lead to improved air quality in the affected areas. This contributes not only to economic, but to social development as well. Lowering the congestion also causes reduction in the transport times. This allows for an increased volume of transported goods. A second significant positive effect of infrastructure development arises from the economic opportunities that the infrastructure provides, chief among which is the improved access. Accessibility to transportation is one of the main determinants of the location choices of firms (Krugman, 1991) and it also allows for more job opportunities for the labour force (Aschauer, 1990).

A common negative effect of the expansion and improvement of the transport infrastructure is the increased number of vehicles (Aschauer, 1990). This could lead to increased air pollution and noise in the nearby areas and therefore worsen the quality of life in these regions. This negative effect can of course be countered with appropriate measures by the government or the road authorities, such as congestion charges or noise reduction technology. Nevertheless, it is assumed that the positive effects of the road infrastructure outweigh the negative ones.

3.4 Other determinants of economic growth

One of the factors that have an influence on economic growth is the foreign direct investments to the host country. Agrawal and Khan (2011) show that if employed correctly, FDI can significantly contribute to an increase in the economic growth of a country. Weber (2011) argues that FDI is one of the main drivers of growth in Eastern Europe and it can significantly influence the economic performance of a country through its relations with exports and productivity.

Taxes are also found to impact the growth rates of the economy, although there is an argument about the exact effect that taxes have. According to Anaraki (2013), higher tax rates limit the ability of individuals to consume and companies to invest in technology improvements, thus limiting the possibilities for increased productivity. Also, an increase in unemployment is observed by the author, strengthening the negative impact on the economy. Contrary to that, Kuismanen and Kamppi (2010) argue that increase in taxes leads to increased government budget and spending, therefore exerting a positive effect on GDP and investment by increased economic performance and growth.

The connection between international trade and economic performance was already hinted in the previous chapter of this paper. It is considered to have a significant positive impact on GDP, hence increased trade flows and trade openness can significantly contribute to increased economic growth (Astorga, 2010).

Another major determinant of the economic performance of a country is its population. Similarly to the tax rates, however, the relationship between population and economic growth is not clear. According to Cai and Lu (2013), while larger population can lead to increased levels of productivity and innovation, which increase economic output and
growth, it can also cause misallocation of production factors, inefficiency of the limited resources and subsequently lower economic growth.

Last, but not least, the level of corruption in a country also influences its economic performance. Similar findings are made by Welsch (2008) and Aidt (2009), who argue that high levels of corruption are associated with lower economic performance. Both papers find evidence of strong negative relationship and subsequently worsened economic development.
4 Empirical settings

This section explains the variables that are included in the analysis. It also discusses the different types of models and tests that are used for the empirical part of the paper.

4.1 Variables

This subsection explains the variables that are used in the model, based on the previous studies. Moreover, it states the expected sign of the relationship between the dependent and independent variables.

4.1.1 Dependent variable

The main focus of this study is to find the impact of infrastructure development on economic growth. Therefore, the dependent variable for this model is the economic growth. The percentage change in GDP per capita is used as a proxy for economic growth. It is measured in constant 2005 US$ in order to take inflation into account. The growth of GDP per capita is used, rather than GDP itself, because this eliminates the problems that might occur from the different size of the countries’ economies. Data for this variable were collected from the World Development Indicators database of the World Bank.

4.1.2 Independent variables

Highway infrastructure growth

The growth of the highway infrastructure is the main explanatory variable of the model. It shows the percentage change in the length of the highways in each one of the countries in the sample group. The literature and theory suggest that the relationship between road infrastructure and growth is a significant one. The expected effect of the infrastructure development on economic growth is a positive one, as supported by previous studies. Data for the length of the highways were collected from Eurostat.

FDI inflows

Foreign direct investment inflow is the first of the control variables. It shows the amount of money, invested in the economy by non-residents. The specific effect of this variable on GDP per capita growth is not of main interest for the model, but since FDI is one of the main determinants of GDP, the variable has to be included in order to make the coefficient for highway infrastructure growth more consistent. The variable is measured in current US$. As shown in the next section of this paper, it is not stationary in level form, so in order to avoid biasness of the results, the first difference of the logarithm was used in the regression model. The expected effect of the FDI inflow is positive and significant. Data for this variable were collected from the World Bank.

Tax rate

Another important determinant of GDP growth is the tax rate. It can be viewed as a proxy for government expenditures in this paper. It is also used as a control variable to help clear the effect of the main independent variable, namely the highway infrastructure growth. The variable is an average of the taxes on income, corporate profits, capital gains, land, securities and other assets. It is measured as a percentage of the revenue, whether realized or not. The expected effect of this variable on GDP per capita growth is unclear according to the ambiguous results from the previous studies. The data for this variable were collected from the World Development Indicators of the World Bank.
Trade openness

Trade openness is an index that shows the impact that trade has on the economy of a country. It is calculated using the amount of imports and exports in relation to the GDP. The bigger the ratio, the larger is the influence of trade on domestic activities. This variable is also used as a control variable. It is expected that the relationship that exists between trade openness and GDP growth has a positive sign and is significant. The index was calculated manually using data for imports, exports and GDP in constant 2005 US$, collected from the World Bank. Furthermore, the variable is taken as the first difference of the log-form to address stationarity issues.

Population growth

The fourth control variable is the growth rate of the population. Similar to the tax rate, population growth does not have a clear impact on GDP per capita growth. Although other variables such as human capital or labour force can better show the impact on economic growth, they were not used in this study as the data didn’t fit the model. The data for the population growth were collected from the World Bank.

Corruption

The last of the independent control variables reflects how the level of corruption in a certain country influences GDP per capita growth for that country. The general assumption is that high levels of corruption are associated with low economic growth, thus showing the negative nature of the relationship. The corruption perception index is used as a proxy for this variable. The index is measured on a scale between 0 and 10. The higher the number, the lower the level of corruption is. The variable is taken in log-form and it is expected to have a positive effect on economic growth. The data were collected from Transparency International.

4.2 Empirical model

This study uses panel data for 21 European countries over 12-year period between 2001 and 2012. The use of panel data allows for combination of the merits of cross-sectional and time series analysis. This gives more reliable coefficients and increases the trustworthiness of the model. Furthermore, combining cross-section and time series results in more observations and increases the available degrees of freedom. An additional advantage of panel data is that it solves some of the problems that are associated with the other two data types. Panel data also gives more reliable and efficient coefficients and better utilizes the dynamics of the changes that occur in the variables (Gujarati, 2004). The general type of the equation is:

\[ Y_{it} = \beta_0 + \beta_1 X_{i1t} + \beta_2 X_{i2t} + \cdots + \beta_k X_{ikt} + u_{it} \]  

In the above expression \( i \) symbolizes the cross-sectional aspect, while \( t \) shows the time series aspect of the variables. \( K \) stands for the number of independent variables.

The first step of the analysis, conducted in this paper, uses an OLS method to determine the relationship between highway infrastructure growth and GDP per capita growth. The equation has the following form:
\[ GDP_{it} = \beta_0 + \beta_1 HWG_{it} + \beta_2 FDI_{it} + \beta_3 TAX_{it} + \beta_4 TROP_{it} \\
+ \beta_5 POPG_{it} + \beta_6 CORR_{it} + u_{it} \quad (2) \]

Where:
- \( GDP_{it} \) is the GDP per capita growth;
- \( HWG_{it} \) stands for the growth of highway infrastructure;
- \( FDI_{it} \) represents the first difference of the FDI inflows;
- \( TAX_{it} \) illustrates the average tax rate;
- \( TROP_{it} \) symbolizes trade openness;
- \( POPG_{it} \) is the population growth;
- \( CORR_{it} \) represents the variable for corruption;

Since the model is set primarily to test the effect of infrastructure growth on economic growth, the coefficient that receives highest interest is \( \beta_1 \). This coefficient is expected to be positive and significant. The other variables that are included in the model are mainly for controlling the unobserved factors that could influence GDP per capita growth and their purpose is to help estimate more clearly the effect of infrastructure growth.

The results of this OLS analysis, however, cannot be trusted completely. A certain level of endogeneity can be expected from the model. Endogeneity between the variables leads to biasness of the results of the OLS model, rendering them inconsistent, thus not able to show the clear effect of highway infrastructure growth on GDP per capita growth. The problem of the model comes from the fact that the growth of the highways can also affect the other independent variables, or the residuals. Better or large road infrastructure contributes to larger FDI inflows (Urxata and Kawai, 2000; Dollar et al., 2005; Kinda, 2013). Moreover, it greatly facilitates international trade and lowers the transportation cost of goods (Khadaroo and Seetanah, 2008; Rehman et al., 2011), which also influences the levels of exports and imports. Other factors that influence economic growth, but are not included in the model (such as labour productivity) can also be affected by development in the highway infrastructure. These factors are contained within the residuals, meaning that there is some sort of correlation between the independent variable and the residuals. Summarizing the abovementioned relations suggests that the development of highway infrastructure influences economic growth both directly and indirectly through the other variables. In order to get a better understanding of the clear effect of highway infrastructure growth, an instrumental variable approach must be used.

### 4.3 Instrumental variable approach

Despite the popularity of the OLS method, sometimes it is believed to give biased and inconsistent results. This happens when there is some sort of deeper relationship between any of the independent variables and the error term, such as high correlation or causality. The error term in any regression model contains factors that cause changes in the dependent variable, but cannot be controlled for by the model. This problem can be solved by using an instrumental variable approach, which gives better estimates than the simple OLS model.

In a simple bivariate equation, such as \( Y_{it} = \beta_0 + \beta_1 X_{it} + u_{it} \), a case could exist where \( X \) is correlated with some of the unobserved factors, expressed by the error term \( u \), which also influence the dependent variable. Because of this correlation, the estimated coefficient from this OLS model (\( \beta_1 \)) would be larger in absolute value than the true causal effect of
the independent variable. In other words, if $X$ changes, it affects $Y$ both directly and indirectly through the error term. The estimated $\beta$ coefficient can be expressed as:

$$\hat{\beta} = \frac{\Delta Y}{\Delta X} = \frac{\Delta Y_X + \Delta Y_u}{\Delta X} = \beta + \frac{\Delta Y_u}{\Delta X}$$  \hspace{1cm} (3)$$

The equation above shows that the change in $Y$ is due to both changes in $X$ and changes in the error term. Hence, the $\beta$ that would be estimated by the model consists of the true effect, plus the changes in the dependent variable caused by the error term. Therefore, this creates a problem when trying to find the clear impact of $X$ on $Y$.

The solution to this problem is to find a separate variable ($Z$), which is called an instrumental variable. This variable must be correlated with the independent variable ($X$), meaning that changes in $Z$ are associated with changes in $X$. At the same time this variable should not be correlated with the error term, hence it causes no changes in it. If such variable exists, changes in it would cause changes in $X$, which subsequently will cause changes in $Y$, but those changes are solely due to $X$ and not the error term. The explicit form of the instrumental variable estimator can be derived by taking the covariance of both sides of the equation with the instrument ($Z$):

$$Cov(Z_{it}, Y_{it}) = Cov(Z_{it}, \beta_0 + \beta_1 X_{it} + u_{it})$$  \hspace{1cm} (4)$$

The right side can be simplified further:

$$Cov(Z_{it}, Y_{it}) = Cov(Z_{it}, \beta_0) + \beta Cov(Z_{it}, X_{it}) + Cov(Z_{it}, u_{it})$$  \hspace{1cm} (5)$$

The first term on the right side expresses the covariance of a random variable with a constant. Hence, this term is equal to zero, because the constant does not vary. Furthermore, the first assumption of the instrumental variable approach could be stated, that is the covariance between the instrument and the error term must be equal to zero, meaning that the instrument does not influence the residuals. According to this assumption, the last term on the right side can be eliminated from the equation. At this point there is only one term left on the right side. Hence, from equation (5) the $\beta$ coefficient can be derived as:

$$\beta = \frac{Cov(Z_{it}, Y_{it})}{Cov(Z_{it}, X_{it})}$$  \hspace{1cm} (6)$$

This leads to the second assumption of the instrumental variable approach: the covariance between the instrument and the independent variable must be different than zero. If it is equal to zero, the instrument is not good and there is no sense estimating the equation.

To summarize, a good instrument must satisfy two conditions:

1. $Cov(Z_{it}, u_{it}) = 0$
2. $Cov(Z_{it}, X_{it}) \neq 0$

The instrumental variable (IV) approach estimation consists of two stages. In the first stage, after the correct instrument is selected, the independent variable, for which it was constructed, is regressed on that instrument and expected values of that variable are generated. In the second stage the original model is estimated using the expected values of
the independent variable, instead of the actual ones. This results in more consistent and unbiased coefficient.

Given that this study is dealing with highway and road infrastructure growth, a suitable instrument seems to be the number of vehicles per 1000 people. This number includes not only cars for personal use, but also trucks and buses for commercial use. This variable was manually calculated using data for the total number of registered vehicles per country (collected from Eurostat) and the total population of the countries in the sample group. The variable is vehicles per 1000 people in order to exclude the effects of different size and population among countries. The logic behind it is that if there are more cars in a certain country, there will be more incentives for development of the road infrastructure, including the construction of highways and the expansion of the highway network. The goals of such development are to reduce congestion of the smaller roads, increase speeds and decrease trip times. Therefore, there is a good reason to believe that the number of vehicles is related to the highway infrastructure growth and it will be tested as an instrument in this model.

Despite the fact that there is more than one independent variable in the model, the principle of the instrumental variable approach is the same. Hence, for the first stage of the estimation, the following equation was tested:

$$\begin{align*}
HWG_{it} &= \beta_0 + \beta_1 CARS_{it} + \beta_2 FDI_{it} + \beta_3 TAX_{it} + \beta_4 TROP_{it} + \beta_5 POPG_{it} + \beta_6 CORR_{it} + u_{it} \tag{7}
\end{align*}$$

In the above equation $CARS_{it}$ stands for the number of vehicles per 1000 people, and the other variables are the same as in the original model. After obtaining the beta coefficients from this equation, the expected values of the highway infrastructure growth variable are estimated. This leads to the second stage of the IV approach, in which the following model is estimated:

$$\begin{align*}
GDPC_{it} &= \beta_0 + \beta_1 HWGIV_{it} + \beta_2 FDI_{it} + \beta_3 TAX_{it} + \beta_4 TROP_{it} + \beta_5 POPG_{it} + \beta_6 CORR_{it} + u_{it} \tag{8}
\end{align*}$$

Here $HWGIV_{it}$ stands for the instrumentally corrected independent variable. This model is the final one, used in this paper, and it is supposed to show the clear effect of highway infrastructure growth on GDP per capita growth. Similarly to the OLS model, based on the theory and literature, it is expected that the coefficient for infrastructure growth will be positive and highly significant.

### 4.4 Granger causality test

The problem with causation between highway infrastructure and growth has an ambiguous nature. In some cases the increase of highway infrastructure indeed causes economic growth, which can be divided into short-term and long-term growth. On one hand, it is possible that the construction of the highways themselves causes short term growth by temporary reducing unemployment, for example. On the other hand, the actual use of the highways causes long-term growth through increased accessibility, larger trade flows, shorter transition times and even increased productivity. Long-term growth is the main focus of government policies and is also given priority in this study. Hence the long-term causality between highway infrastructure and economic growth will be investigated later on.
In a different type of situation, economic growth causes highway growth by creating a larger demand for adequate infrastructure that could accommodate the increased amount of economic activity, such as increased trade, larger migration flows, or need for shorter transport times. Because of that “chicken versus egg” uncertainty a Granger causality test was conducted to spread light on the issue.

The Granger causality test assumes that information that is contained in the data can be used to predict the future changes in the same data. In other words, the test suggests that the change in a variable is caused by something that happened in a previous time period. The test works by regressing the variables on their lagged values. A panel Granger causality test is used to better reflect the global aspect of causality. The test uses GDP per capita and the instrumented variable for highway infrastructure growth. According to previous studies, infrastructure is expected to cause economic growth.

4.5 Data description

This section describes the main properties of the data, before continuing to the estimation of the model. The variables that are used for the regression are described, as well as the changes that are made to them. Due to the different number of observations for the different variables, unbalanced panel is used for estimating the impact of highway infrastructure on economic growth.

Stationarity

Before any tests or regressions were done with the data, it was checked for stationarity using the Augmented Dicky-Fuller test (see Appendix 2). The results showed that two of the variables were non-stationary, namely FDI inflows and trade openness. To address this problem, these variables were taken in first difference.

Multicollinearity

A variance inflation factor (VIF) test was performed to check the data for multicollinearity (see Appendix 3). It showed that there is no reason to believe that any of the variables, used in the model are correlated with each other. Furthermore, Appendix 4 shows the correlation matrix for all the variables that are used in the regression model. It is visible that there is no strong relationship between the different variables. Only a few of them express a positive correlation, which is considered weak. The strongest relationship is the one between GDP per capita growth and trade openness. The value of 0.57 shows, however, that the connection between these two variables is not strong enough to influence the outcome of the model. The same can be said for the relationship between tax rate and population growth and FDI inflows and trade openness. The results from the correlation matrix show that there is no incentive to remove any of the variables from the model, as the connections between them are too weak to influence the outcome.

Autocorrelation and heteroscedasticity

A conducted test for autocorrelation shows that the data has problems with it (see Appendix 5). It is noted that this can affect the results of the estimation. Breush-Pagan test was conducted to check the data for heteroscedasticity (see Appendix 6). The Prob>chi2 = 0.3741 is not significant. This means that the data has no problems with heteroscedasticity.
Descriptive statistics

Table 1 presents summary of the variables. Despite the fact that growth rates are used for some of the variables in order to eliminate the size effect of the respective values for different countries, there is still a big difference between the minimum and maximum of those values. The largest GDP per capita growth is experienced in Lithuania (between 7% and 11%) while the lowest is for Estonia (-14.573%). When it comes to highway infrastructure growth, the gap between the minimum and maximum is enormous. Although this variable does not reflect the actual length of the motorway network in order to avoid size discrepancies, it shows that some countries put more efforts in the development of their highway system. On average, Ireland has the largest growth of highway infrastructure, but the maximum value for this variable is achieved in Romania. In general, less developed or developing countries show larger growth in the highway infrastructure than developed countries. Population growth is used in the same sense as the other two growth variables – it takes care of the different size of the population in different countries. Both the FDI inflows and trade openness variables are in first difference log-form. This reduces their volatility and helps for the analysis by eliminating the time trend, which can cause spurious results. Tax rate and corruption are taken as logarithms to avoid autocorrelation.

Table 1. Descriptive statistics.

<table>
<thead>
<tr>
<th></th>
<th>GDP growth</th>
<th>Highway growth</th>
<th>FDI inflows</th>
<th>Tax rate</th>
<th>Trade openness</th>
<th>Population growth</th>
<th>Corruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>2.242</td>
<td>5.627</td>
<td>0.066</td>
<td>2.913</td>
<td>0.029</td>
<td>0.189</td>
<td>1.743</td>
</tr>
<tr>
<td>Maximum</td>
<td>11.152</td>
<td>101.770</td>
<td>3.809</td>
<td>3.669</td>
<td>0.197</td>
<td>2.878</td>
<td>2.292</td>
</tr>
<tr>
<td>Minimum</td>
<td>-14.573</td>
<td>-25.899</td>
<td>-4.603</td>
<td>1.860</td>
<td>-0.145</td>
<td>-2.258</td>
<td>0.955</td>
</tr>
<tr>
<td>Std. Dev.</td>
<td>4.021</td>
<td>12.347</td>
<td>0.905</td>
<td>0.466</td>
<td>0.055</td>
<td>0.765</td>
<td>0.330</td>
</tr>
<tr>
<td>Obs.</td>
<td>252</td>
<td>236</td>
<td>210</td>
<td>241</td>
<td>231</td>
<td>250</td>
<td>252</td>
</tr>
</tbody>
</table>
5 Results

This section discusses the results of the empirical model. First the results from the OLS analysis are shown. Then the relationship between the instrument and the highway growth is discussed. Finally, the results from the IV approach are presented.

5.1 OLS

This section contains the results of the simple OLS regression. Table 2 shows the impact of infrastructure growth on GDP per capita together with the other control variables. The results show that the highway infrastructure growth has a slight negative impact on economic growth, which contradicts the theory and literature. The coefficient, however, is not statistically significant, meaning that infrastructure appears to have no effect on GDP per capita growth.

Table 2. Results from equation (2): OLS regression.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>(Standard Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.438</td>
<td>(2.096)</td>
</tr>
<tr>
<td>Highway growth</td>
<td>-0.007</td>
<td>(0.018)</td>
</tr>
<tr>
<td>FDI inflow</td>
<td>0.805***</td>
<td>(0.288)</td>
</tr>
<tr>
<td>Tax rate</td>
<td>0.401</td>
<td>(0.630)</td>
</tr>
<tr>
<td>Trade openness</td>
<td>32.074***</td>
<td>(4.796)</td>
</tr>
<tr>
<td>Population growth</td>
<td>-1.210***</td>
<td>(0.425)</td>
</tr>
<tr>
<td>Corruption</td>
<td>-1.718*</td>
<td>(0.922)</td>
</tr>
<tr>
<td>R²</td>
<td>0.418</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>186</td>
<td></td>
</tr>
</tbody>
</table>

Notes: *** denotes significance at 1% level; * denotes significance at 10% level; standard errors in parenthesis; GDP per capita growth is the dependent variable; FDI inflow and Trade openness are in first difference; Tax rate and corruption are in logarithmic form.

The results from this model are to serve purely as comparison to the instrumental variable approach, hence not much focus should be given to them. Nonetheless, a discussion of these results is needed. All the control independent variables, except tax rate, are significant at different levels. The expected positive effect of FDI inflows is confirmed by the highly significant coefficient, which shows a relatively strong impact. Attracting large amounts of foreign investments contributes to the increase of fixed capital, responsible for increased production and market capabilities. FDI can also decrease unemployment and increase labour productivity, hence the positive effect on economic growth.

This analysis shows that tax rate is not a significant factor that influences GDP per capita growth. Hence, the positive relationship, shown by the coefficient, cannot be trusted. Trade openness proves to be highly significant and very important for GDP growth. The index shows that for the countries from the sample group international trade relations plays a significant role for the economy. From the table above it can be seen that population
growth has a significant negative impact on economic growth. To some extent, this is supported by the theory and the negative relationship is not surprising.

The last variable of the analysis shows a surprising negative effect of the level of corruption. The variable used as a proxy (corruption perception index) increases in value as the level of corruption in the country decreases. Hence a large value would mean less or no corruption, which would benefit economic growth, as supported by the theory. Based on this, the expected sign of the coefficient is positive. The negative sign of the relationship, however, could be explained by the general assumption that there is less corruption in developed countries, suggesting that the level of the corruption perception index will be high. Furthermore, previous studies suggest that developed countries experience lower economic growth than developing countries. These factors combined together suggest that the negative coefficient is due to the different combination of corruption level and economic growth in different countries.
5.2 The instrument

As stated in the methodology section of this paper, a good instrument will cause change in the main independent variable, but will not be related to the other explanatory variables or the residuals of the model. Furthermore, it has to satisfy the two conditions of covariance – the covariance between the instrument and the independent variable must be different from zero, while the covariance between the instrument and the residuals must be equal to zero.

Prior to checking the actual influence of the number of vehicles on the independent variable, the suitability of the instrument must be tested. The following table shows the covariance between it and the residuals and main independent variable. As seen from the table, this instrument satisfies both conditions for covariance mentioned above and in the methodology section.

Table 3. Covariance between the instrument, the main independent variable and the residuals.

<table>
<thead>
<tr>
<th>Number of vehicles</th>
<th>Highway growth</th>
<th>Residuals</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-307.9434</td>
<td>-6.88E-14</td>
</tr>
</tbody>
</table>

The negative covariance between the number of vehicles per 1000 people and the highway infrastructure growth shown in table 3 is surprising and it hints for negative relationship outcome from the regression analysis. Nevertheless, since the selected instrument proves to be suitable, the analysis can move to the next step – regressing the main independent variable on the instrument and other control variables from the model. The variable is stationary in the level form, hence no modification is required. The results from this regression are shown in table 4.

Table 4. Results from equation (7): the instrumental variable.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>16.561*</td>
</tr>
<tr>
<td></td>
<td>(9.492)</td>
</tr>
<tr>
<td>Cars</td>
<td>-0.029**</td>
</tr>
<tr>
<td></td>
<td>(0.011)</td>
</tr>
<tr>
<td>FDI inflow</td>
<td>0.853</td>
</tr>
<tr>
<td></td>
<td>(1.280)</td>
</tr>
<tr>
<td>Tax rate</td>
<td>1.430</td>
</tr>
<tr>
<td></td>
<td>(2.804)</td>
</tr>
<tr>
<td>Trade openness</td>
<td>-4.656</td>
</tr>
<tr>
<td></td>
<td>(20.760)</td>
</tr>
<tr>
<td>Population growth</td>
<td>2.886</td>
</tr>
<tr>
<td></td>
<td>(1.897)</td>
</tr>
<tr>
<td>Corruption</td>
<td>-0.617</td>
</tr>
<tr>
<td></td>
<td>(5.192)</td>
</tr>
<tr>
<td>R²</td>
<td>0.083</td>
</tr>
<tr>
<td>N</td>
<td>164</td>
</tr>
</tbody>
</table>

Notes: ** denotes significance at 5% level; * denotes significance at 10% level; standard errors in parenthesis. Highway infrastructure growth is dependent variable; FDI inflow and Trade openness are in first difference; Tax rate and corruption are in logarithmic form.

As can be seen from the table above, the number of vehicles per 1000 people is significantly and negatively related to highway infrastructure growth. A possible explanation of this type of relationship could be the fact that in general, people can afford to buy more
cars, hence increase the number of vehicles per 1000 people, in countries with higher quality of life, meaning countries that are considered rich and developed. In such countries the level of highway infrastructure is also high. Hence, there is no need or economic incentive to expand the existing infrastructure. The small coefficient shows that this instrument has a small economic effect on infrastructure growth, but nevertheless it was used for the IV approach for statistical reasons.

Table 4 also shows that none of the other independent variables influence highway network growth. This shows that there is no strong relationship that could influence indirectly GDP per capita growth through highway infrastructure growth and therefore lead to biased results. After the instrument variable is established in this stage, the expected values of the highway infrastructure growth variable are obtained and used in the next step.


5.3 IV Results

This subsection presents the final findings of this paper, connecting road infrastructure and economic growth. The outcome of the second stage of the instrumental variable approach is presented below:

*Table 5. Results from equation (8): the instrumental approach.*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>-0.187</td>
<td>(2.870)</td>
</tr>
<tr>
<td>Highway growth (IV)</td>
<td>0.194**</td>
<td>(0.089)</td>
</tr>
<tr>
<td>FDI inflow</td>
<td>0.490</td>
<td>(0.313)</td>
</tr>
<tr>
<td>Tax rate</td>
<td>0.223</td>
<td>(0.641)</td>
</tr>
<tr>
<td>Trade openness</td>
<td>34.379***</td>
<td>(4.962)</td>
</tr>
<tr>
<td>Population growth</td>
<td>-1.692***</td>
<td>(0.542)</td>
</tr>
<tr>
<td>Corruption</td>
<td>-0.117</td>
<td>(1.213)</td>
</tr>
</tbody>
</table>

R²: 0.414
N: 173

Notes: *** denotes significance at 1% level; ** denotes significance at 5% level; standard errors in parenthesis. GDP per capita growth is the dependent variable; FDI inflow and Trade openness are in first difference; Tax rate and corruption are in logarithmic form.

Table 5 shows the results from the instrumental variable approach about the influence of highway infrastructure growth on economic growth. It is clear that unlike the OLS method, the IV approach makes the main independent variable statistically significant. Moreover, the positive coefficient shows a considerable economic effect, which has been expected and is in line with previous research and theory. The use of the IV technique makes two of the independent variables insignificant, compared to the OLS method, namely the FDI inflows and corruption.

The results show that next to a statistical one, highway infrastructure also has a significant economic effect on GDP per capita growth. According to Table 5, 1% increase in the highway construction growth leads to close to 0.2% increase in GDP per capita growth. This could be considered as a positive effect, proving that more attention should be paid to the development of highway infrastructure. The impact on economic growth could be attributed to several factors. First, a larger highway network allows for larger trade flows. More goods can be transported in less time and with higher speed. This facilitates trade and could make a certain region that was recently connected to the highway network be more competitive. Second, here also comes the advantage of accessibility. As mentioned before in this paper, in developed countries a new piece of highway connects with the already existing infrastructure and provides access to all the points of that network. Of course it is not reasonable to attribute as much importance to the accessibility of the highway network as the accessibility provided by normal roads and other means of transportation, but nevertheless, it is also considered a significant factor when it comes to possibilities of better and faster transportation.
Larger and better highway network also provides means for increased movement of people and migration between regions or cities. A new stretch of highway can significantly reduce travel times and give the opportunity to people to travel to nearby cities to work – something they would not have done if the travel times are too long and travel costs are too high. The increased movement and consequent interaction between people inevitably create knowledge spillovers, which are proven to be beneficial for the overall economic performance. Furthermore, productivity can also be increased, due to increased migration, which additionally contributes to larger economic growth. The theory and previous studies consider well-developed transport infrastructure to attract more foreign investments. It increases and improves the access to markets, which is one of the main incentives for firms to expand in other countries. This increases the overall economic activity in the country and therefore positively impacts GDP per capita growth.

When it comes to the control variables in the model, the results are similar to the OLS method, with few exceptions. Here the coefficients for FDI inflows and corruption become insignificant. Trade openness and population growth keep their significance levels, while the magnitude of their effect increases. The coefficient for tax rate remains insignificant.

Trade openness, similarly to the OLS estimation, shows considerable positive impact on economic growth. Although the coefficient from this estimation is larger than the one obtained by the OLS method, the nature of the relationship remains the same – trade openness proves to be very important for determining the level of economic growth. This additionally strengthens the assumption that international trade plays a significant role in any country’s economy. This being said, it must be clarified that almost all the countries from the sample are members of the European Union. This removes the obstacles for international trade, so the countries can fully benefit from goods and services produced abroad. The only exception is Turkey, which is not an EU member, but has trade agreements with the Union. These agreements considerably facilitate trade and also contribute to the big positive impact of trade openness on GDP per capita growth.

The coefficient for population growth is again similar to the original one from the OLS method. Here, however, the negative impact of increased population on economic growth seems to be larger in magnitude. Probable misallocation of government resources can explain the negative sign. Resources that could have otherwise been used for improvements in different areas of the economy (infrastructure, subsidies for manufacturers, etc.) are now directed towards supporting the ever-growing needs of the increased population. It is possible that in some countries the increasing population actually becomes a burden for the economy when resources are allocated to help poor regions. This still proves the idea that increased population can turn out to be a burden for the economy of a country, rather than an asset.

Overall, the results show that three out of the six independent variables significantly influence economic growth. Out of them two have a positive impact and one a negative, but in general they are all consistent with the expectations. This model gives reason to believe that the increase of highway infrastructure leads to increased overall economic performance.
5.4 Granger causality results

This section investigates the causal relationship between infrastructure growth and economic growth. According to the previous studies discussed in the literature review section of this paper, it is expected that highway growth causes GDP per capita growth. It must be noted, however, that this test reflects the data for the 21 selected European countries for the years between 2001 and 2012. It may not fully reflect the true causal relationship between economic growth and highway infrastructure growth.

When the test is conducted with the two variables, lagged between one and four times, there appears to be no causal relationship between them. Although it is believed that the construction of highways creates short-term growth, the impact could be too small to be considered a causal effect. Instead, the economic growth can be attributed to other factors that are not included in this test.

Between five and six lags there is unidirectional causality between highway infrastructure growth and economic growth. The highway infrastructure Granger-causes economic growth through increased ability to handle larger goods flows, or by allowing for easier and faster movement of people. In some cases the increased possibility of people traveling faster to nearby cities or industrial zones helps the creation of knowledge spillovers. This would not have existed if the infrastructure was not adequate enough to allow for the abovementioned easier and faster movement of people. Furthermore, more infrastructure increases accessibility, which facilitates transactions between individual economic subjects.

At seven lags there is bidirectional causality between highway infrastructure growth and GDP per capita growth. This is the only occasion, according to the Granger causality test, when economic growth causes infrastructure growth. Although seven years might be considered as too long a period for the effects of increased economic growth to create demand for infrastructure, it is still a plausible explanation. On the other hand, the benefits from more developed highway infrastructure continue to Granger-cause increases in the economic growth.

When the variables are lagged eight times or more, no causal relationship is observed between them. According to the data, this is the time frame in which the economy adjusts to the increased opportunities, provided by the extended highway network, and the initial effects of its expansion wear off.

The Granger causality test confirms that there is a causal relationship between highway infrastructure growth and economic growth, since the infrastructure Granger-causes GDP per capita, as predicted by the theory and previous studies on that matter. It also confirms the findings of this paper that highway infrastructure growth significantly influences economic growth.
6 Conclusion

The purpose of this paper was to investigate the impact of highway infrastructure development on economic growth. To investigate this impact, a panel dataset was constructed using 21 European countries over a period of 12 years. First, the relationship between highway infrastructure growth and GDP per capita growth is examined using simple OLS analysis, and then, by utilizing the advantages of the instrumental variable approach, clearer idea of the effect that infrastructure has on economic growth is presented. Finally, the conducted Granger causality test sheds light on the causal relationship between the dependent and the main independent variable.

The initial results from the OLS analysis did not show a significant relationship between highway infrastructure growth and economic growth. They, however, illustrate that four of the other control variables (FDI inflows, trade openness, population growth and corruption) have a strong impact on GDP per capita growth. The results are consistent with previous studies. Because there might be some issues with endogeneity in the OLS model, an instrumental variable approach was used to more clearly define the true relationship between highway infrastructure development and economic growth. The number of vehicles per 1000 people was selected as an instrument and the econometric model was re-estimated using this approach.

The results from the IV estimation show that highway infrastructure growth has indeed a significant positive effect on economic growth in terms of GDP per capita growth. The positive impact could be attributed to several factors, such as increased trade flows, faster transportation times, lower transportation costs, and so on. Improvements of the accessibility and flexibility of the highway network facilitate the transportation of goods, thus facilitating trade, which was again proven to have considerable impact on the economic situation. Furthermore, a more advanced highway network allows for larger mobility of the population, creating suitable environment for knowledge spillovers across space and better distribution of production factors in terms of labour force and human capital. Trade openness proves to be highly significant for the economies of the countries in the sample group. The index shows that international trade has a major influence on domestic activities in those countries. Hence, trade policies that encourage and facilitate international trade can significantly contribute to the increase of economic growth. The negative relationship between population growth and GDP per capita growth was expected and confirms the findings by previous researchers that it is possible for a larger population to become a burden on the economy of a country (in terms of increased expenditures for health care, education and social help), rather than an increased resource.

The results from the Granger causality test show that initially there is no causality between the two variables. It is believed that the construction of highways creates short-term growth, but the effect is likely too small to be considered as causal. Eventually, at 5 and 6 lags, the expansion of the highway network Granger-causes economic growth. This proves that transport infrastructure indeed has a positive impact on economic performance. The “chicken versus egg” dilemma continues to exist however, since it was also found that at 7 lags bidirectional causality between economic growth and highway infrastructure growth exists. After that the effects of the expansion of the highway network are believed to wear off as the economy adjusts to the new situation.

The results of this study show that more attention should be paid to the possible benefits that could be utilized by increase in the development of the highway infrastructure. Proper government policies, aimed at the transport infrastructure, can increase the amount of
investments attracted by the specific country, thus contributing to the increase of economic output. Since highways are preferred by transportation companies because of the higher speed and shorter time for transportation, measures towards development of the highway infrastructure can lead to increased trade flows that stimulate better economic performance. The positive effects of the highway network should be considered in more detail and exploited in a better fashion to increase even further the impact on economic growth.

As stated in this paper, infrastructure has different effects in developed versus developing countries. These effects are not investigated in this paper, but certainly deserve more attention, since they could lead to different government policies that are applied in different countries. Future studies can also focus on the efficiency and quality of the highway network, rather than its quantity, since many developed countries improve the existing infrastructures instead of expanding it. One thing is clear, however - the highway infrastructure plays a major role in the economic performance of a country, and its impact will continue to increase.
References


Appendix

Appendix 1

List of the countries, used in this study
3. Croatia 10. Ireland 17. Slovakia

Appendix 2

Results from the ADF unit root test

<table>
<thead>
<tr>
<th>Variable</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP per capita growth</td>
<td>0.0586</td>
</tr>
<tr>
<td>Highways growth</td>
<td>0.0021</td>
</tr>
<tr>
<td>FDI inflow</td>
<td>0.7932</td>
</tr>
<tr>
<td>Tax rate</td>
<td>0.0021</td>
</tr>
<tr>
<td>Trade openness</td>
<td>0.9611</td>
</tr>
<tr>
<td>Population growth</td>
<td>0.0100</td>
</tr>
<tr>
<td>Corruption</td>
<td>0.0623</td>
</tr>
</tbody>
</table>

Results from the ADF unit root test for the differenced variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI inflow (1st difference)</td>
<td>0.0024</td>
</tr>
<tr>
<td>Trade openness (1st difference)</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

Appendix 3

Variance inflation factor (VIF) test

<table>
<thead>
<tr>
<th>Variable</th>
<th>VIF</th>
<th>SQRT VIF</th>
<th>Tolerance</th>
<th>R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDPG</td>
<td>1.27</td>
<td>1.13</td>
<td>0.785</td>
<td>0.215</td>
</tr>
<tr>
<td>HWG</td>
<td>1.07</td>
<td>1.03</td>
<td>0.935</td>
<td>0.065</td>
</tr>
<tr>
<td>DLNFDI</td>
<td>2.04</td>
<td>1.43</td>
<td>0.490</td>
<td>0.510</td>
</tr>
<tr>
<td>DLNTRP</td>
<td>1.18</td>
<td>1.09</td>
<td>0.847</td>
<td>0.153</td>
</tr>
<tr>
<td>LNTAX</td>
<td>1.78</td>
<td>1.34</td>
<td>0.561</td>
<td>0.439</td>
</tr>
<tr>
<td>POP</td>
<td>1.82</td>
<td>1.35</td>
<td>0.548</td>
<td>0.452</td>
</tr>
<tr>
<td>LNCORR</td>
<td>1.56</td>
<td>1.25</td>
<td>0.642</td>
<td>0.358</td>
</tr>
<tr>
<td>Mean VIF</td>
<td>1.53</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Appendix 4

Correlation matrix

<table>
<thead>
<tr>
<th></th>
<th>GDP growth</th>
<th>Highway growth</th>
<th>FDI inflows</th>
<th>Tax rate</th>
<th>Trade openness</th>
<th>Population growth</th>
<th>Corruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>GDP growth</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Highway growth</td>
<td>-0.030</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FDI inflows</td>
<td>0.357</td>
<td>0.013</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tax rate</td>
<td>-0.189</td>
<td>-0.021</td>
<td>0.014</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trade openness</td>
<td>0.570</td>
<td>-0.003</td>
<td>0.396</td>
<td>-0.153</td>
<td>1.000</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population growth</td>
<td>-0.372</td>
<td>0.105</td>
<td>-0.057</td>
<td>0.508</td>
<td>-0.245</td>
<td>1.000</td>
<td></td>
</tr>
<tr>
<td>Corruption</td>
<td>-0.299</td>
<td>-0.114</td>
<td>0.002</td>
<td>0.479</td>
<td>-0.193</td>
<td>0.517</td>
<td>1.000</td>
</tr>
</tbody>
</table>

Appendix 5

Cumby-Huizinga autocorrelation test

H₀: No serial correlation

<table>
<thead>
<tr>
<th>Lags</th>
<th>Chi2</th>
<th>df</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24.001</td>
<td>1</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Appendix 6

Breusch-Pagan heteroscedasticity test

H₀: Constant variance

<table>
<thead>
<tr>
<th>Chi2 (1)</th>
<th>Prob&gt; Chi2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.79</td>
<td>0.3741</td>
</tr>
</tbody>
</table>