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Transport infrastructure and its impact on the economic growth in the EU

Bachelor's thesis

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Declaration of Authorship

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Prague, July 31, 2020

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Abstract

The main objective of this thesis is to determine whether a relationship exists between transport infrastructure and economic growth. This topic has been discussed by many studies, however no relevant study has measured the difference in impact between countries under the historic influence of the Soviet Union. A dataset of 27 EU member states for the period 1995 to 2007 for the length of roads, motorways and railways per capita was analyzed based on their historic membership in the Warsaw pact treaty. A production function approach was applied and the results show positive impact of motorways and railways on the growth of GDP per capita.

Keywords transport infrastructure, economic growth, production function, Warsaw pact, railway, roads, capital

Title Transport infrastructure and its impact on the economic growth in the EU

Abstrakt

Hlavním cílem této práce je určit jestli existuje vztah mezi dopravní infrastrukturou a ekonomickým růstem. Toto téma bylo diskutováno v mnoha studiích, ale žádná relevantní studie nerozlišovala mezi rozdílem dopadu u státu pod historickým vlivem Sovětského svazu. K ověření dopadu byla analyzována data délky silnic, dálnic a železnic na obyvatele pro 27 států Evropské Unie pro roky 1995 až 2017 s ohledem na historický vliv Varšavské smlouvy u jednotlivých států. Práce pro analýzu používá produkční funkci a výsledky ukazují pozitivní vliv dálnic a železnic na růst HDP na obyvatele.

Klíčová slova dopravní infrastruktura, ekonomický růst, produkční funkce, Varšavská smlouva, železnice, silnice, kapitál

Název práce Dopravní infrastruktura a její dopad na ekonomický růst v EU

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Acronyms

EU European Union

GDP Gross Domestic Product

US United States

TFP Total Factor Productivity

OECD Organisation for Economic Co-operation and Development

PIM Total Factor Productivity

US Perpetual Inventory Method

OLS Ordinary Least Squares

PPS Purchasing Power Standard

VAR Vector Autoregression

C.E.M.S. Central European Member States

NATO North Atlantic Treaty Organization

Bachelor's Thesis Proposal

Author	Adam Peterka
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Proposed topic	Transport infrastructure and its impact on the economic growth in the EU

Research question and motivation Vast number of studies have been carried out to analyze the relationship between transport, capital infrastructure and economic growth. Further analyses were conducted to observe the causal relationship between a public investment injection and an increase in economic growth. This thesis will study the correlation between the level of transport infrastructure across EU member states and its impact on the growth of economy. It will try to answer the question of whether investments in transport infrastructure can boost the growth of country's economy.

Hypotheses There is a limited number of studies for the EU member states sample. The analysis will include capital stock of public transport infrastructure and compare the effects in "western" and "post-socialist" countries to analyze whether the elasticities differ across these regions.

Methodology The thesis will utilize the Production Function approach, first used by Aschauer (1989) and discuss the impact of transport infrastructure stock on the GDP. The implementation of Cobb-Douglass production function was chosen as the best reliable option given available data and the nature of analysed hypothesis. The selected methodology will utilize panel data for European countries from the period 1995-2007.

Data will be obtained from 3 sources - Eurostat, OECD Transport forum and the Statistical pocketbook of the European Commission. Eurostat offers detailed data on GDP growth and other economic indicators. OECD Transport forum database includes data on Transport infrastructure investments for OECD member states.

Road, motorway and railway data will be sourced from the European Commission database.

Outline

1. Introduction
2. Review of existing literature
   (a) Analysis of existing approaches
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5. Methodology
6. Analysis results
7. Conclusion

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1 Introduction

A still ongoing discussion is the identification of the scale of influence of transport infrastructure investments on economic growth on regional and local level. Taking apart clearly apparent benefits of time-savings and comfort of travel, but rather focusing on measurable benefits of the increased economic output measured in GDP yearly changes, the question stands to whether these actually exist and if they can be measured.

Many studies have set the objective to analyze whether transport infrastructure investment can boost economic growth. With enormous investments in transport infrastructure, the European economy has also seen economic growth. Are these linked? The supporting transport infrastructure and increased transport capacity allows for businesses to operate and substantiates economic exchange. Private businesses are able to extend their market operations with connections to new town, cities and countries, or with improved infrastructure that reduces transportational and operational costs. In general, any investment that makes movement of people and goods easier speeds up economic exchanges and brings new business opportunities.

Let's take a step back and see how transport infrastructure improvements built today's economy. Take, for example, food production. It is one of the key Italian exports, with just Parmesan being a $4.1bn business (ItalianFood.net 2019). Italian Parmesan cheese can only be made in a restricted area in northern Italy, in the region of Emilia Romagna. No other production can call their cheese Parmesan. Out of the 148,000 tons produced in a year, more than 10,000 tons of are being exported to the US - the second biggest importer of Parmigiano Reggiano, after France (ItalianFood.net 2019). Such business connection would not be possible without reliable transport connections between US and Italy.

Transportation itself also represents large percentage of the Italian GDP. "The share of transportation in the gross domestic product of developed countries accounts for approximately 6-12 %. It is considered that today, in the era of globalisation, the competitive advantage of each economy depends, inter alia, on facilitating more efficient transport of people and goods, while the key obstacle can be the lack of efficient and high-quality transport infrastructure." (Lenz *et al.* 2019)

In EU alone, transportation and storage services (including postal and courier activities) accounted to about 5 % of total Gross Value Added in EU in 2017 according to Commission (2019). With expansion of online shopping, home deliveries and pickup services, this number is expected to grow further. Retailers are researching ways to improve speed, delivery efficiency and reduce transportation costs of getting their product the the final customer. Without reliable transport infrastructure and available capacity, the expansion is very limited.

The transport industry represents a total of 5.3 % employed EU workforce. (Commission 2019) Even though these numbers are also expected to grow in the short term, with investments in autonomous transport they are eventually expected to decline as human employees are going to be replaced by automated forms of transport, like autonomous vehicles or drones.

In 2017, households have spend about 30 % (out of the total €1 trillion household transport expenditure) on vehicles purchases and another 50 % on the maintenance and operation (e.g. gas). Spendings in transport services are very low (ca. 20 %) compared to overall vehicle purchases, however we are seeing an upwards growth trend of 36.2 % in the harmonised index of consumer prices from 2005 Commission (2019). This proves the popularity of shared economy in the transportation field as car lease plans, ride-sharing and increased popularity of taxi services shift transportation from a good to service.

Another key factor is the transport capacity. This especially applies to overcrowded areas, big cities and highly developed countries, like the USA, Germany, Benelux countries or capital cities in general. Here, whenever the maximum transport capacity level is met, transporters (individuals, companies etc.) have to halt their movement due to congestions. Any delays or waits due to insufficient transport capacity result in costs for the economy.

This paper reviews available studies on the topic of infrastructure and economic growth and aims to answer the question as to whether better transport infrastructure means more growth for the economy.

A dataset of 27 EU member states for the period 1995 to 2007 for the length of roads, motorways and railways per capita will be analyzed based on their historic membership in the Warsaw pact treaty to group between post-socialist states and those under the historic influence of NATO. Will the impact of transport infrastructure be higher for - Czechia, Slovakia, Poland, Hungary, Romania, Bulgaria, Estonia, Latvia and Lithuania? This thesis breaks down the transportation impact and answers to which extent and whether this impact is significant

2 Evidence in literature

Vast number of studies have been carried out to analyse the relationship between transport, capital infrastructure and economic growth. Further analyses were conducted to observe the causal relationship between a public investment injection and an increase in economic growth. Most studies build on work by Aschauer (1989), Barro (1990) and a recent one by Canning & Pedroni (2008), who found significant positive impacts of transportation investments and infrastructure on economic growth.

Aschauer (1989) examines relationship between the total factor productivity (TFP), stock o public capital and government spending. His empirical analysis utilises annual data on output, hours worked, private capital, productivity, capital stock and flow government-spending from the period 1949 to 1985 in the US economy. With his main objective to measure the effectiveness of public policy as the US government has started to move away from utilizing fiscal policy to control the economy, he finds significant importance of public investment decisions - specifically "additions to the stock of nonmilitary structures such as highways, streets, water systems, and sewers." (Aschauer 1989, p. 197) He identifies that a 1% increase in public capital stock would raise the total factor productivity by 0.39%.

Munnell (1992), who used a similar approach to carry out the analysis, argues that the impact of public investment on the private sector is too large to be trusted and does not find evidence that public infrastructure investments impact growth more than private ones. He further argues that most of the impact goes for improving society, well-being, environment and other measures not reflected in the GDP. Eventually, however, he finds that elasticity of public capital stock is 0.34. The evidence presented in this study suggests that 1% increase in public capital stock raises the total output by 0.34%.

In recent years, there has been an increasing amount of literature challenging studies such as Aschauer (1989), Munnell (1992) and one with similar approach by Eberts & Stone (1986). A number of authors have begun to examine the econometric approach of the study and identified shortcomings, mainly with the fact that the authors omit the "reverse causation" effects, i.e. the impact of GDP on infrastructure. Also, studies from Tatom (1991) and Gramlich (1994) criticised trends in data (not taking stationarity of the data into account) and pointed out problems with spurious correlation. After accounting for stationarity most reported studies would arguably yield statistically insignificant results.

Many authors also suggest that the impact of infrastructure investments may be counteracted by the subsequent additions of taxes to finance them. In literature (Eller 2011), this phenomenon is referenced as the "Barro Curve". According to Barro (1990), the growth effect of additions to infrastructure expenditures is more pronounced in less developed countries. As the size of the investment reaches a certain treshold ($\tau = \alpha$, where α represents returns to scale and τ the tax rate) , the economic growth is deterred by rises in τ. This is further confirmed in a study by Gupta *et al.* (2005), who points out the importance of public investments mainly in countries with poor infrastructure and low economic growth.

2.1 Defining public capital: data challenges

The definition of public capital varies across studies as authors take different approaches and set proxies in their research. Large number of studies define public capital as the sum of physical infrastructure owned by the government (i.e. roads, highways, railways, airstrips, airports, water facilities, sewerage, hospitals, public buildings, schools etc.). Most studies do not count military expenses towards public capital. These, sometimes referred to as "core infrastructure" (see Bom & Ligthart 2013, chap 2), are further segregated to analyse individual fields of public capital. For example, Aschauer (1989) analysed its core and non-core components. Other relevant studies, like Lenz *et al.* (2019) target solely transportation infrastructure, which this thesis focuses on.

Usually, public national capital stock data are not reported and have to be constructed for the purposes of analysis. International datasets are available for OECD member countries but, OECD itself "recommends to be very careful in using the data for international comparisons" (Berlemann & Wesselhöft 2014) as the provided datasets are a combination of OECD estimations and available national data. General public capital estimations are usually done trough the method of perpetual inventory (PIM) - interpreting economy‘s capital stock as an inventory.

In calculations, researches typically utilize data of past investments adjusted for depreciation. Sturm & de Haan (1995) used a special form of PIM, which expects that all assets are scraped when their lifetime expires. The dead-loss method is specified as follows:

$$Cap_t = Cap_{t-1} + Inv - Dep_t \tag{2.1}$$

Here, *Cap* stands for the capital stock, *Inv* for gross investments and *Dep* for depreciation. According to Sturm & de Haan (1995), the dead-loss method is the most effective method as it expects that the lifetime and capacity of most infrastructure is remained through reparation and maintenance.

Several other lines of studies have used physical measures of infrastructure - kilometres of paved roads, length of highways, railways, waterways etc. An important study by Canning & Pedroni (2008) follows and adapted model by Barro (1990) and utilizes annual data for kilometres of paved roads, kilowatts of electricity-generating capacity and the number of telephones from the period 1950-92 for a panel of OECD countries. They argue that government investment data aggregates many types of infrastructure fields and report them based on the construction costs rather that the real value of composition effects. Also, this approach takes away differences in prices, efficiency and regulations across countries. In other words, public capital investments are regarded to be homogeneous in terms of their impact on economic growth.

Generally, in the literature, we find 3 approaches to estimation of the GDP and public investment dynamics. First, the "production function" approach, which expands the standard production function with a public infrastructure component. Second, the cost-benefit approach measures the effects on economy in terms of cost savings. Finally, VAR models used to predict dependencies among variables in multiple time series.

2.2 Production function approach

Before famous Aschauer's work, most studies considered only labor and private capital as components of the production function. One of the first implementing public capital in the production function was Mera (1973) who conducted a study estimating productivity of the "social overhead capital" in Japanese regions and reported transportation to be the most effective part of infrastructure in the period of restructuring of the Japanese economy. Mera (1973) further indicated that public capital was comparable to private capital in terms of marginal productivity. Other studies considered the role of public infrastructure, but none of them received such attention as Aschauer (1989). For empirical purposes, the Cobb-douglas production function is usually denoted as follows:

$$Y_t = A_t * f(L_t^{\alpha}, K_t^{\beta}, G_t^{\phi}) \tag{2.2}$$

where Y_t represents a measure of real aggregate output of goods and services of the private sector, L_t labour employment, K_t aggregate private nonresidential capital input, and A_t a measure of productivity (TFP). The variable G_t, represents a flow of services from the government sector. After transforming the equation in logarithms, i.e. taking natural logarithms on both sides of 2.2, the unobserved effect change ($logA_t$) must be expressed in terms of observables to estimate a log-linearized model. The most commonly used specification is $lnA_t = \alpha_0 + \chi_t + \gamma + \epsilon_t$, which then gives the following equation:

$$lnY_t = \alpha_0 + \chi_t + \gamma + \epsilon_t + lnL_t + lnK_t + lnG_t + \epsilon_t \tag{2.3}$$

Or in the simplest form:

$$lnY_t = lnA + \alpha lnK_t + \beta lnL_t + \phi lnG_t + \epsilon_t \tag{2.4}$$

Publications that concentrate on the European Union more frequently adopt a similar approach like Canning & Pedroni (2008).[1] A recent study carried out by Comission (2014), analysing the Developments and Impact on Growth, has indicated that "in the long term, both transport and electricity infrastructures are positively correlated with GDP." The study measured the sum of total length of road and rail traffic per network kilometre and their correlation with the GDP growth. These results are consistent with other empirical researches and prove a positive relationship between these measures. The magnitude of the relationship varies between calculation methods and countries, but generally ranges between 0.006 and 0.84 in elasticity of change. These results are however significant and positive. The panel data analysis has shown that the innovations effect growth in the long term, which might also be reflected by innovation efficiency gains. The study suggested that the infrastructure provisions require

[1] Comission (2014) or Lenz *et al.* (2019)

time to materialise and investments shock usually do not lead to a permanent impact of the GDP growth.

The study concludes with analysis of investment patterns across EU-28 member states. Between EU founding members states, infrastructure investment has been generally low over the past 15 years, the rest of EU countries seem to be adjusting to a boom in the past and new member states observably invest higher sums of money in order to catch up with other developed member states. These investments are usually incentivised by the European budget. Therefore to-date economic conditions present opportunities for increases in infrastructure investments.

2.3 The Cost-Function Approach

Another approach to estimation of transport impacts on economic growth is the cost function used for example by Sturm *et al.* (1997) or Cohen & Morrison Paul (2004). The cost function approach measures the effects of public infrastructure on the economy in terms of cost savings, i.e. examines whether the cost of output declines with higher public capital stock. One main shortcoming of the production function is that it disregards the standard marginal productivity theory, therefore several studies, like Duggal *et al.* (1999), have been trying to solve this with the cost function. It includes an unpaid factor of production which is estimated as an endogenous variable. Moreover, the factor prices in this model are an exogenous variable. The separation of exogenous prices and endogenous input quantities solves the problem of causality direction. A major handicap of the cost-function is that it requires a perfect mix of production factors, which is increasingly difficult to estimate on the national level. The basic cost function is structured as follows:

$$C = (p_L, p_K, Y, G, t) \tag{2.5}$$

where p_L and p_K are factor prices of Labor and Capital, respectively, Y is the output, G is the stock of public capital and t is the technological change. In empirical studies, targeted measures of the cost function usually employ a translog function[2] or a Generalised Leontief function[3].

For example, Paul (2003) studied the effects of public infrastructure on

[2]for example Moreno *et al.* (2003)

[3]for example, Cohen & Morrison Paul (2004), Nadiri & Mamuneas (1996)

the cost structure and productivity in the private sector in Australia for the period of 1968 to 1995. The author has found significant results of public infrastructure on productivity of the private sector. He further claimed, that "public capital serves as a substitute for both private capital and labour" and with the approach he used, the reported elasticities were actually higher than those from studies using the production-function approach.

Cohen & Morrison Paul (2004) investigated the relationship using a cost-function model with a generalized Leontief maximum-likelihood approach. They analyze public stock of highways using the PIM in all US states for the sample period of 1982-1996. Their model separates intra and inter-state effects of public infrastructure investments and takes in account spill-over effects due to interaction between the two. By taking in account the spill-over effect the elasticity increases from -0.15 to -0.23.

2.4 Vector Autoregression Models

Several studies, for example Research (2014) or Ligthart (2000), utilize vector autoregression (VAR) models. In VAR models, there is no *a priori* causality among the jointly determined variables, (Romp & de Haan 2007) but in order to estimate a VAR model a causal structure has to be imposed. This model allows to analyse k time series regressions, with all lags of k series as regressors. Through consideration of a limited number of variables, the VAR model allows testing for indirect effects between the variables in the model. Torrisi (2009) defines a VAR model with four variables (also used by Kamps (2004), Kamps (2006) and Broyer & Gareis (2013)) (output, employment, private capital and public capital) as follows:

$$\begin{aligned} y_t &= \delta + \sum_{i=1}^{L_y} \alpha_i y_{t-i} + \sum_{i=1}^{L_g} \gamma_i g_{t-i} + u_t \\ g_t &= \eta + \sum_{i=1}^{L_y} \beta_i y_{t-i} + \sum_{i=1}^{L_g} \rho_i g_{t-i} + \epsilon_t \end{aligned} \tag{2.6}$$

Here, L_y and L_g represent the number of lags of y and g, respectively. Error terms (u_t, ϵ_t) are also considered and expected not to be correlated with past information of the studied variables. VAR models can be estimated using standard OLS and, if specified correctly, yield consistent and normally distributed estimates.

Broyer & Gareis (2013) estimated a VAR model for France, Italy, Germany and Spain and concluded that an increase in public infrastructure is associated with an increase in output, employment and private investment. They find that a 1 Euro investment in transport infrastructure led to a raise in GDP by 14 EUR. They further demonstrated, that an investment shock lasts twice as long in less developed countries compared to developed ones. In times of economic decline, infrastructure investments have a higher impact, according to their examination of the multiplier for different economic regimes.

Out of the three above mentioned approaches, production function approach was selected for this paper as it is the most documented and researched. Papers using the production function approach also provide fairly consistent results of elasticities across different studies.

3 Data description

This chapter describes the data used for the analysis of the relationship between infrastructure capital and GDP across EU member states. The main research question of this paper is: "What is the relationship between transportation infrastructure and economic growth in EU countries?". We have collected data from Eurostat (2020b), Canning & Pedroni (2008), Comission (2014), IMF (2017) and OECD (2017),to combine a sample for 27 EU member states for the period 1995 to 2017 to carry out panel data analysis. Our dataset is based on Chapter 4, which demands observations for economic growth, capital stock and transport infrastructure.

3.1 Economic growth

As a proxy for economic growth the model uses GDP as the dependent variable. GDP is a measure of all goods and services produced in the economy, less the value used in their creation. The studied dataset was built from data collected from the Eurostat (2020a) database, which provides annual measures in the purchasing power standard (PPS) for 27 EU member states. The PPS measure levels differences in price levels across countries, which allows us to set is as a meaningful an economic performance indicator. In our model the GDP is divided by the total population of the country in order to produce per capita numbers. Per capita PPS measures usually serve as good indicators of economic performance and standards of living; however, they fail to account for wealth distribution and other externalities. However, for this research such measure can be used since our goal is not to measure social effect but the impact of economic performance.

Variable	$\bar{x}$	**s**	**Min**	$\tilde{x}$	**Max**
GDP	21776.3	11013.2	4607.0	20593.0	77018.3

Table 3.1: Descriptive statistics of the GDP

3.2 Transport infrastructure database

Transport infrastructure data is difficult to obtain and usually various datasets have to be combined in order to produce time-consistent estimates. The database in this research was built by combinations of two datasets - Canning (2007) and Commission (2019). The first dataset updated in 2007 by Canning, covers the period 1950-2005 and provides data on the length of paved roads and length of railways for 153 countries. In order for us to be able to conduct a most to-date analysis we further merged this dataset with data provided by the European Commission. The Statistical pocketbook of EU Transport provides an overview of annual transport-related statistics for 28 (in 2019) EU member states. For overlapping years we took averages of both datasets and filled missing values to create full set of observations. Both datasets provided comparable observations, which were mostly identical or varied slightly.

The length of railways is considered as one of the variables of interest and measured in km. Eurostat (2020b) provides datasets for railway infrastructure based on the railway type, for example high-speed or electrified railways etc. This data is however inconsistent and unavailable for all periods and countries, therefore we will not consider such measure in the analysis. Annual data on the length of railway network for each country in our model assumes the same quality of railway across the studied cross-section. In our sample, we only take in account 25 EU member states, because Malta and Cyprus do not have any railway infrastructure.

Road infrastructure data was collected from Eurostat (2020b). Our dataset includes annual data on the total number of roads, the length of paved and unpaved roads. Observations of these two road level measures are limited, therefore for our model we are going to use just the total length of all roads. Commission (2019) further provides consistent data for the length of all motorways in EU countries for our specified period. Adding this data to our observed model can yield some interesting findings. However, we also have to note there are two EU member states with no motorway infrastructure - Malta and Latvia. Using motorways as explanatory variable will therefore evict these observations.

All three infrastructure variables were converted to per capita values by simple division using population data available from Eurostat (2020c). In review, we obtained the total length of roads, total length of motorways and total length of railways in per capita terms.

Variable	$\bar{x}$	s	Min	$\tilde{x}$	Max
rail	0.000005	0.000063	0.000000	0.000000	0.000758
road	0.013256	0.009195	0.000977	0.012870	0.044827
motorway	0.000000	0.000000	0.000000	0.000000	0.000000

Table 3.2: Descriptive statistics of the transport infrastructure (in km per capita)

3.3 Capital stock

Capital can be catalyst for economic growth. In order to further increase the robustness of our model, we are including capital stock value observations in our sample. The dataset was collected from IMF (2017) and includes values of general capital stock constructed using the PIM on general government investment flows in constant 2011 US dollars for 170 countries from 1960 to 2017. The IMF dataset is constructed using PIM method, similarly to Gupta *et al.* (2005) and Kamps (2006). Specifically, it combines multiple channels of private and public investments, transforms them into real costs and with assumptions about the depreciation rate calculates individual capital stock observations. The initial capital stock was determined based on the "synthetic time series approach".(IMF 2017)

In order to include this dataset in our model, constant US 2011 dollars had to be transformed into EUR values and converted to per-capita numbers. We used the average exchange rate for 2011 between USD and EUR from OECD (2017) to convert the observations to EUR.

3.4 Control variables

To further increase the stability of our model, control variables can be introduced to the model to minimize biases. The employment rate was selected as an indicator denoted to have impact on the economic growth.

The discussion of employment as GDP relationship has been ongoing far longer than the question of infrastructure impacts. The most influential work is by Arthur Okun, who looked at the relationship between a country's unemployment and GDP growth rates. The so-called Okun's law states that a 2% increase in economic output corresponds to a 1% decline in the rate of cyclical unemployment; a 0.5% increase in labor force participation; a 0.5% increase in hours worked per employee; and a 1% increase in output per hours worked (labor productivity). This approximation based on Okun's empirical research, in other words states that one percent increase in the cyclical unemployment rate is associated with two percentage points of negative growth in real GDP (Gilbert (1973)).

In our final estimation, we expect the coefficient of employment to be significant and positive.

3.5 Grouping "post-socialist" states

Another objective of this paper is to determine the scale of impact and compare between two groups of studied countries - those under the historical influence of Warsaw pact (hereafter refered to as "post-socialist"), a defense treaty by the Soviet Union after World War II, and those under NATO.

The Warsaw Pact, formally known as the Treaty of Friendship, Cooperation and Mutual Assistance, was originally composed of the Soviet Union and seven of its satellites in Eastern Europe - Czechoslovakia, Albania, Bulgaria, East Germany, Hungary, Poland and Romania. It was an organization formed in Warsaw undertaking all its members to collective defence under a joint military command and permitting the maintenance of soviet military forces on the territories of the member states. The Soviet Union formed this alliance as a counterbalance to the North Atlantic Treaty Organization (NATO), a security treaty established between Western European states, Canada and the United States in 1949.

The Warsaw Pact was based around the principle of market control and economic cooperation, including both military agreements and production quota. In reality, the Soviet Union decided both the military and economic policies for all of the Warsaw Pact's member states. Ideologically, the Soviet Union acted as the leader of the global socialist movement. Consequences were set for those countries who would undermine core socialist ideas and Communist Party functions.

In order to answer the studied question of whether the impact of transport infrastructure on economic growth is more significant in Eastern-Europe, we introduce a measure to mark "post-socialist" countries. In this selection we include the following countries - Czechia, Slovakia, Poland, Hungary, Romania, Bulgaria, Estonia, Latvia and Lithuania.

A dummy variable is introduced in our model to mark post-socialist countries. A dummy variable is one that takes only the value 0 or 1 to indicate membership in a group with specific criteria. The system of classification assigns 1 for the above mentioned countries and 0 to the all other.

Variable	Levels	$\bar{x}$	s	Min	$\tilde{x}$	Max
GDP	0	25432.65314	11103.09335	5378.60000	23532.20000	77018.30000
	1	14207.54950	5691.16309	4607.00000	13939.30000	27080.30000
	all	21776.26759	11013.22820	4607.00000	20592.95000	77018.30000
rail	0	0.00000	0.00000	0.00000	0.00000	0.00000
	1	0.00001	0.00010	0.00000	0.00000	0.00076
	all	0.00001	0.00006	0.00000	0.00000	0.00076
motorway	0	0.00000	0.00000	0.00000	0.00000	0.00000
	1	0.00000	0.00000	0.00000	0.00000	0.00000
	all	0.00000	0.00000	0.00000	0.00000	0.00000
road	0	0.01432	0.00920	0.00098	0.01418	0.04483
	1	0.01141	0.00892	0.00241	0.00971	0.02996
	all	0.01326	0.00920	0.00098	0.01287	0.04483
empl	0	70.65217	5.78777	57.60000	71.30000	82.50000
	1	68.11730	4.28333	57.50000	68.70000	77.00000
	all	69.83802	5.47676	57.50000	70.30000	82.50000
capital	0	23967.60009	10620.05968	6331.72742	21743.56934	61540.25399
	1	10351.48751	5373.74680	3364.12216	9098.29356	22611.91636
	all	19428.89590	11224.55334	3364.12216	18652.66730	61540.25399

Table 3.3: Descriptive statistics of our dataset

Interesting data descriptive observations can be made from the available dataset. Table 3.3 displays basic analytical measures of our complete dataset grouped into post-socialist and other countries statistics. No interesting observations for rail and motorway can be made as the average length per capita is too small to be displayed in our table. We can however see that the average GDP per capita in post-socialist states is much lower, then in the rest of the countries in our dataset.

Figure 4.1 is a scatter plot of relationship between GDP per capita, the length of roads per capita and length of motorways per capita. Individual entries are marked based on their membership in post-socialist group. An interesting observation can be made from the plotted line, which is upwards sloping. The countries with higher GDP per capita, therefore have a more dense motorway infrastructure in terms of per capita measures. (For the purpose of visualisation, the total length of motorways and roads and motorways have been multiplied by a constant, that however does not change the direction of the relationship.)

By looking at the group distribution of post-socialist states (in blue), most of these countries are at the bottom lower part of our graph. A clear outlier to this is Lithuania, on the upper left of our graph. We therefore may expect the effect of transport infrastructure investments to be higher in western countries.

Figure 3.1: Scatter plot: The relationship between GDP, roads and motorways

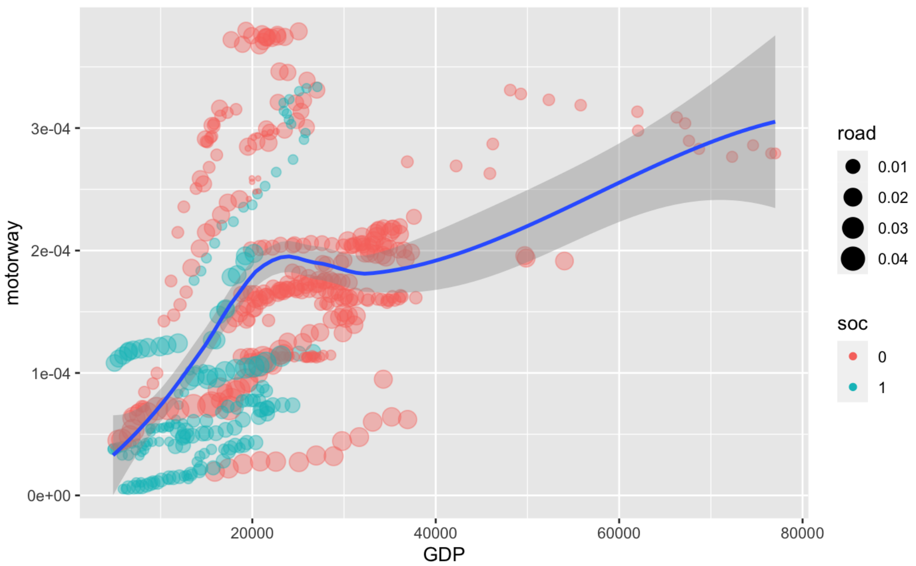
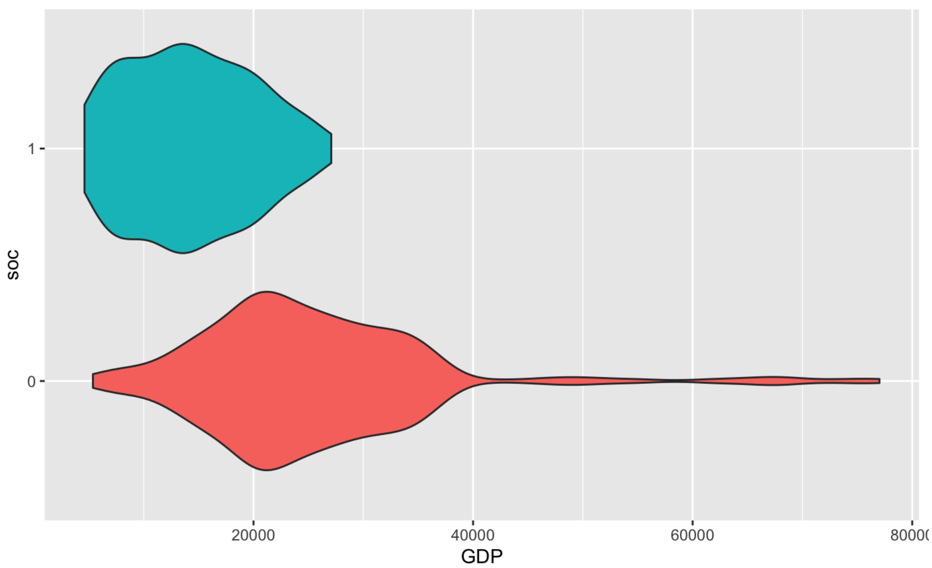


Figure 3.2, displays a violin distribution of GDP per capita compared between post-socialist and non-post-socialist countries. The maximum rate of GDP per capita in post-socialist states is 27000 EUR, however outside this group countries attain much higher rates of GDP.

Figure 3.2: Distribution of GDP for the dummy variable



4 Methodology

The following chapter introduces the methodological approach and the theoretical background of the model. This paper was prepared by adapting the procedure used by Canning & Pedroni (2008), Comission (2014) and Lenz *et al.* (2019). The implementation of the Cobb-Douglass production function was chosen as the best reliable option given available data and the nature of the tested hypothesis. The selected methodology utilizes panel data for European countries to empirically test the effects of transport infrastructure. Panel data, i.e. cross-sectional observations of objects (countries, in our case) across time periods will allow us to observe causal relationships in studied countries given their specific characteristics. The panel dataset includes 27 EU member state countries during the period 1995 till 2017, a total of 621 observations.

The deployed econometric model will include 5 variables: economic growth (GDP), the value of capital in terms of PIM (CAPITAL), motorway infrastructure, rail infrastructure (RAIL), roads infrastructure (ROAD) and the employment rate (EMPL). In other words, by analysing GDP as a dependent variable we specify the following function of explanatory variables:

$$GDP = f(CAPITAL, MOTORWAY, RAIL, ROAD, EMPL) \tag{4.1}$$

4.1 Panel data analysis

Panel data regressions observe a static sample for several time periods. A basic model specified by Wooldridge (2016), assumes parameter homogeneity, i.e. that the coefficient of the explanatory variable and the intercept are not time dependent. A standard unobserved effects panel model includes an error term that has two separate components - the idiosyncratic error u_{it} and the unobserved effects error α_i. The whole model looks as follows:

$$y_{it} = \beta_0 + \beta_1 x_{it} + \alpha_i + u_{it} \tag{4.2}$$

There are 3 main approaches to estimating the coefficients in panel data models available for our dataset:

1. **Pooled OLS (P.O.L.S.)** Wooldridge (2016) describes Pooled Ordinary Least Squares method as the ideal, when our panel model contains a different sample for each time period (the so-called pooled data). This unfortunately is not the case for our sample, because we are studying the same set of countries for the observed period and the countries are not homogeneous (the economic and political structure differs across regions). We can however include the model estimates in our regression results to see if they differ from other methods. The core assumption is that the fixed effect α_i must not be correlated with the explanatory variable x_{it}. If this assumption is violated, we get a heterogeneity bias.

2. **Fixed effects (F.E.)** is used for estimating effects that are not time fixed, i.e. estimating time varying variables only. The unobserved effect α_i and the time-constant independent variables are removed before the estimation. In our case, the *soc* variable and the intercept will be excluded from the model as the grouping of post-socialist states does not change over time. The model therefore looks as follows:

$$\tilde{y}_{it} = \beta \tilde{x}_{it} + \tilde{u}_{it} \tag{4.3}$$

   where $\tilde{y} = y_{it} - \bar{y}_i$, $\tilde{x} = x_{it} - \bar{x}_i$ and $\tilde{u} = u_{it} - \bar{u}_i$. The main assumption of the fixed effects approach is the strict exogeneity of the independent variables, random sampling and no perfect linear relationships among the regressors, under these assumptions the F.E. estimator is unbiased. The idiosyncratic error term is usually uncorrelated with the regressors, however the unobserved effects (α_i) error can be more frequently correlated with the regressors, which would yield inconsistent and biased OLS estimates. This is usually solved with a Fixed-effects (FE) transformation model (also known as the *within transformation*). This method uses time demeaning to control for variables.

   In panel data analysis F.E. estimation is a priori assumed as the most appropriate for the analysis, the thesis examines the economic model with all three different estimators and by specific testing decides on the best suited.

3. **Random effects (R.E.)** The most crucial assumption of the random effects estimation is that there is no correlation between the unobserved effect and individual independent variables across time.In case when α_i is uncorrelated with the explanatory variables, the Random-effects model is used as asymptotically more effective method. In R.E. estimation the intercept (α) is added and α_i has zero mean. (Wooldridge 2016)

$$y_{it} = \alpha + \beta x_{it} + \alpha_i + u_{it} \tag{4.4}$$

   In general, the correlation between α_i and x_{it} can be analysed with the Hausman test, which detects endogenous variables in a regression model (see Hausman (1978)).

In our analysis we are going to test for endogeneity and further decide on the best model to be used in the calculations.

4.1.1 Hausman test

Hausman test is used to decide between fixed or random effects estimation. By running the Hausman test we set the null hypothesis that the preferred model is random effects vs. the alternative the fixed effects. In essence, we are testing whether the error term u_{it} is correlated with our regressors, which they are not under the null hypothesis. By running the FE and RE models, saving the estimates and performing the Hausman test, with bellow specified hypotheses, we decide to use FE or RE.

$$\begin{aligned} &H_0 : \text{the difference in coefficients is not significant} \\ &H_1 : \text{one model is inconsistent} \end{aligned} \tag{4.5}$$

If the p-value is lower than our chosen level of confidence of .01, .05 or .1 then we would reject the null hypothesis. In the case of significant difference between the coefficients due to $corr(u_{it}, x_{it}) \neq 0$, the FE estimator would be safer as it would get rid of the correlated effects and produce unbiased and consistent estimates of coefficients. On the other hand, when the difference is not large enough, as in our case, the random effects estimator is consistent and we prefer it for its efficiency.

4.1.2 Testing for heteroskedasticity

The need for homoskedasticity ($Var(u_{it}|X) = \sigma^2$) is one of the classical assumptions of OLS estimation. Heteroskedasticity means "differently scattered", i.e. variances of the errors vary across time and depend on explanatory variables. In case of its presence, the model would yield unreliable variances, standard errors, and higher than expected t and F statistics. A simple detection can be done by plotting the residual values against the fitted values. A more analytical approach is the Breusch-Pagan-Godfrey LM test. Based on the results, we decide to use heteroskedasticity robust errors.

4.2 Our model

As specified above, this analysis uses the approach described by Canning & Pedroni (2008), which utilizes the Cobb-Douglas production function, specified as:

$$Y_{it} = A_{it}K_{it}^{\alpha}G_{it}^{\beta}L_{it}^{\gamma}U_{it} \tag{4.6}$$

Here, Y is the GDP of a country i in year t, A is the factor of productivity, K is the stock of other assets in the respective country and year, G is the stock of infrastructure assets (infrastructure capital), L is labor and U is the error term. Similarly to Canning & Pedroni (2008), we make several assumptions to form our model. First, for simplicity, we assume a constant savings rate and complete depreciation of both public and infrastructure capital. Second, we will assume constant returns to scale and that infrastructure investments reduce other types of capital investments, since they are financed from savings. Therefore:

$$y_{it} = a_{it} + \alpha k_{it} + \beta x_{it} + \gamma l_{it} + \epsilon_{it} \tag{4.7}$$

Third, we proxy the labor force with the total population. Fourth, the share of factor productivity (technical change) and the size of labor force is determined by an exogenous stochastic process. Solving our equation in per capita terms and taking logs in 4.6, we derive[1]:

$$y_{it} = a_{it} + \alpha k_{it} + \beta x_{it} + \epsilon_{it} \tag{4.8}$$

[1]For full derivation see Canning & Pedroni (2008)

All variables above are specified in per capita log terms. For simplicity, and following Comission (2014), we use a simplified model as:

$$y_{it} = a_{it} + b_1 x_{it} + u_{it} \tag{4.9}$$

where, i is a country for (i = 1,...,27), t is time (t = 1995,...,2017), y_{it} is the GDP per capita in EU27 2020 PPS, x_{it} is the level of infrastructure per capita in country i at time t, u_{it} is the error term, and a_i & b_1 are the correlation coefficients of our variables.

Given available data and following approach by Pradhan & Bagchi (2013), we expand our explanatory variable x_{it} into three different parts: the value of capital stock per capita ($capital_{it}$), the length of paved roads per capita ($road$), length of motorways per capita ($motorway_{it}$) and the length of railways per capita ($rail_{it}$), for country i at year t. The capital values are reported in 2011 constant EUR. For simplicity, we assume that all roads and railways are of the same quality across the countries in our dataset.

$$gdp_{it} = a_i + b_1 capital_{it} + b_2 road_{it} + b_3 motorway_{it} + b_4 rail_{it} + u_{it} \tag{4.10}$$

To increase robustness of our analysis, we introduce a control variable specified in Chapter 3 in order to minimize biases. Similarly to Lenz *et al.* (2019), we will use the employment rate (*empl*). Our model will look as follows.

$$gdp_{it} = a_i + b_1 capital_{it} + b_2 road_{it} + b_3 motorway_{it} + b_4 rail_{it} + b_5 empl_{it} + u_{it} \tag{4.11}$$

where the dependent variable is GDP in PPS, used as a proxy for economic growth, b_i are the coefficients of determination of our explanatory variables.

Logarithmic transformations of variables are used to handle non-linear relationship between independent and dependent variables in a regression model. Using a logarithm of one or more variables the exponential relation is transformed a into linear. Log transformations are often recommended for skewed data, such as monetary measures or demographic measures. Our model is expected to have a degree of skewness, therefore we will transform the model to a log-log format. In this case all variables are log-transformed and the interpretation is given as expected percentage change in the dependent variable when the independent variable(s) increases by certain percentage. The coefficient of our log independent variable is referred to as an elasticity. Initially, it might seem logical to for some types of infrastructure to be measured in terms of density (for example, lengh of roads per km^2), however the Fixed effects estimation would yield equivalent results when dividing by any other constant. In our model, all variables except $empl_{it}$ will be log transformed and in per capita terms. The employment indicator is a ratio of emloyed x unemployed group of population, therefore no logarithmic transformation is needed. Our transformed log model looks as follows:

$$\begin{aligned} \log(gdp_{it}) = a_i + b_1 \log(capital_{it}) + b_2 \log(road_{it}) + b_3 \log(motorway_{it}) \\ + b_4 \log(rail_{it}) + b_5 empl_{it} + u_{it} \end{aligned} \tag{4.12}$$

In order to determine the appropriate empirical approach, we first have to determine the level of correlation.

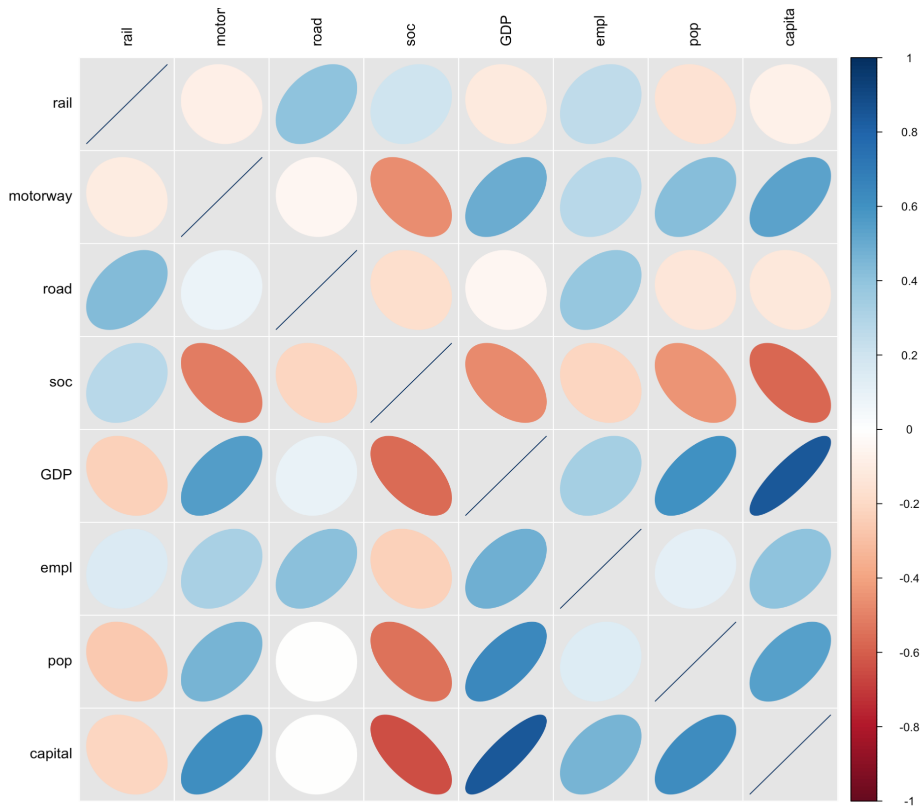
4.3 Correlation analysis

In order to analyze relationships between individual variables, a correlation analysis is carried out. Figure 4.1 displays the strength and direction of relationship between two variables. According to the figure, a moderate negative relationship is present between our dummy variable for post-socialist states and motorways, GDP, capital and employment. The correlation coefficients of GDP and capital and motorways and capital have strong positive relationship. Multicollinearity of variables can be further tested with the variance inflation factor.

4.4 Dummy variable: Warsaw pact member states

Our dataset includes a grouping variable for post-socialist states. Introducing a dummy variable to our model will allow us to distinguish the effect in the two respective groups. A dummy variable will be incorporated in the same way as other explanatory variables in the regression model.

Figure 4.1: Correlation matrix



In order to estimate the effect of road infrastructure on capital in post-socialist states, we run the following equation:

$$\log(gdp_{it}) = a_i + b_1 \log(capital_{it}) + b_2 \log(road_{it}) + b_3 \log(motorway_{it}) + b_4(rail_{it}) + b_5 empl_{it} + b_6 soc_i + u_{it} \tag{4.13}$$

Explanatory variables in OLS models often have interactions among each other. Similarly, dummy variables can also have interaction effects between each other, and these interactions can be depicted in the regression model. We can further let our soc_i variable interact with other explanatory variables.

$$\log(gdp_{it}) = a_i + b_1 \log(soc_i * capital_{it}) + b_2 \log(capital_{it}) + b_3 \log(motorway_{it}) + b_4 \log(road_{it}) + b_5 \log(rail_{it}) + b_6 empl_{it} + b_7 soc_i + u_{it} \tag{4.14}$$

Here, interaction variable ($\log(soc_i * capital_{it})$) captures the interaction effect of the individual continuous variable $capital_{it}$ and the dummy variable soc_i.

Alternatively, it is also referred to as a slope-indicator variable, because it permits the change in the slope of the relationship.

In our final model for estimation we will include interactions for all our variables and compare the elasticity of individual coefficients based on the effect of post-socialist grouping.

5 Result findings

In this chapter on results and their subsequent commenting, we summarise the findings of 3 standard panel regressions for our model from Chapter 4. The results also include other further described instruments to analyse the relationship between post-socialist and other states. To select the best model we will evaluate endogeneity, the value of adjusted R-squared and significance of individual coefficients.

The R-squared shows the explanatory power of the model on the dependent variable. With values between 0 and 1, the higher the proportion of variance of the explanatory variables influences the dependent variable. Another indicator we will be using to measure reliability of a coefficient is the significance, measured in p-value (where $*$ = p<0.1; $**$= p<0.05 and $***$ = p<0.0).

5.1 Regression analysis

We begin with estimation of coefficients in Model 4.13. The estimated results of P.O.L.S., FE and RE are reported in Table 5.1. The first, second and third columns show results for P.O.L.S. (only for comparison), F.E. and R.E. estimators, respectively. The model with the highest adjusted R-squared is the R.E. model, however the difference to other models is not so large. According to the obtained results, only rail, capital, motorways and employment coefficients are significant in the R.E. model.

Based on the Breusch-Pagan-Godfrey LM test for heteroskedasticity, all reported coefficients and their standard errors are calculated based on a robust covariance matrix of parameters for a fixed effects or random effects panel model according to the White method (see White (1980)). The reported standard errors (in parentheses) are therefore heteroskedasticity robust.

In order to decide which model is best suited for our dataset we carry out the Hausman test, to test for error and explanatory variable correlation.

Table 5.1: Regression results

	Dependent variable:		
	log(GDP)		
	P.O.L.S.	*F.E.*	*R.E.*
	(1)	(2)	(3)
log(capital)	0.671***	0.712***	0.834***
	(0.036)	(0.176)	(0.113)
log(motorway)	0.015*	0.153*	0.052*
	(0.009)	(0.079)	(0.033)
log(rail)	−0.003	0.011*	0.008**
	(0.008)	(0.007)	(0.004)
log(road)	0.051***	0.097	0.081
	(0.011)	(0.117)	(0.083)
soc	0.074*		0.363***
	(0.039)		(0.129)
empl	0.005*	0.027**	0.025***
	(0.003)	(0.011)	(0.009)
Constant	3.746***		2.761
	(0.381)		(1.788)
Observations	452	452	452
R^2	0.736	0.735	0.752
Adjusted R^2	0.732	0.718	0.749
Residual Std. Error	0.248 (df = 445)		
F Statistic	206.729*** (df = 6; 445)	235.014*** (df = 5; 424)	1,351.881***
Note:			*p<0.1; **p<0.05; ***p<0.01

5.1.1 Hausman test

Hausman test results are reported in Table 5.2. The estimated p-value is small (less than 0.05) therefore we can reject the null hypothesis of F.E. estimator being preferred. Based on these results, we can conclude that R.E. regression is preferred to F.E. regression taking in account the endogeneity results.

Table 5.2: Hausman test results

Test	**Chi-square value**	**DF**	**P-value**
FE vs. RE	29.628034	5	0.0000

5.1.2 Results

All variables in our preferred R.E. model highlight a positive impact on economic growth. However out of the studied transport infrastructure coefficients, only rail and motorway coefficients are significant (p-value < 0.1). This shows the importance of motorway and railway infrastructure and its impact on economic growth in EU countries.

The average output elasticity of public capital (*cap*) is very similar and significant across all models, in the RE model it amounts to 0.834, which is much more than for example found by Bom & Ligthart (2013), who estimated the elasticity at 0.106. Capital is significantly positive, which implies important effect on the GDP. We can interpret our findings as one percent rise in the value of capital per capita, would yield a 0.834% rise in GDP per capita. Countries with higher per-capita capital measures are likely to have higher economic growth.

Out of the three studied transport explanatory variables, railway infrastructure is the most significant in our regression analysis. Any rise by one percentage point in railways length per capita would yield a 0.008% rise in GPP per capita. Even though the impact is not substantial, it is significant and positive. This finding is in conflict with results by Lenz *et al.* (2019) and Pogrletchi (2014), who found the effect to be negative. It is important to note that our data sample was different to Lenz *et al.* (2019) who analyzed 11 C.E.M.S. countries.

On the other hand, the road infrastructure coefficient is not significant in our model, therefore we are not able to make any conclusions. This may be a little unexpected and not in conformity with other studies on this topic like Lenz *et al.* (2019), Comission (2014) or Canning & Pedroni (2008), who find significant positive impact of this explanatory variable.

As expected, the *empl* control variable is in all cases positive and significant, this proves our theory of positive impact of employment on the level of GDP.

Unexpectedly, the coefficient of our dummy variable for post-socialist states is also positive and very large. This may be due to unobserved data discrepancies or dataset structure.

5.2 Interactions for post-socialist states

Table 5.3 presents results of our extended model with dummy variable interactions specified in Equation 4.14. Multiple regressions have been run, specifically for five R.E. and one P.O.L.S. models for comparison, where each dummy variable interaction is added in the consecutive model. All explanatory variables are logged except for employment and our dummy variable, as they are in ratio and binary form, respectively.

Table 5.3: Dummy variable interaction regression results

	Dependent variable:					
	log(GDP)					
	P.O.L.S.	*R.E.*	*R.E.*	*R.E.*	*R.E.*	*R.E.*
	(1)	(2)	(3)	(4)	(5)	(6)
log(capital)	0.734***	0.834***	0.860***	0.830***	0.824***	0.748***
	(0.039)	(0.113)	(0.135)	(0.116)	(0.106)	(0.143)
log(motorway)	0.097***	0.052*	0.049	0.023	0.048	0.140**
	(0.023)	(0.033)	(0.032)	(0.023)	(0.032)	(0.055)
log(road)	0.073***	0.081	0.084	0.067	0.048	0.099
	(0.019)	(0.083)	(0.077)	(0.080)	(0.051)	(0.091)
log(rail)	−0.099***	0.008**	0.008*	0.009**	0.010	−0.161**
	(0.023)	(0.004)	(0.004)	(0.004)	(0.007)	(0.062)
I(log(capital) ∗soc)	−0.032		−0.040			
	(0.056)		(0.144)			
I(log(motorway) ∗soc)	−0.044*			0.081		
	(0.025)			(0.066)		
I(log(road) ∗soc)	0.065**				0.065	
	(0.027)				(0.164)	
I(log(rail) ∗soc)	0.105***					0.172***
	(0.024)					(0.063)
soc	3.157***	0.363***	0.754	3.740	0.658	7.218***
	(0.652)	(0.129)	(1.395)	(2.752)	(0.779)	(2.563)
empl	0.001	0.025***	0.024***	0.023**	0.025***	0.021**
	(0.002)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Constant	2.954***	2.761	2.408	1.713	2.595	0.883
	(0.405)	(1.788)	(2.097)	(1.368)	(1.735)	(1.292)
Observations	452	452	452	452	452	452
R^2	0.780	0.752	0.754	0.759	0.754	0.778
Adjusted R^2	0.775	0.749	0.751	0.755	0.751	0.775
Residual Std. Error	0.227 (df = 441)					
F Statistic	155.961*** (df = 10; 441)	1,351.881***	1,363.524***	1,394.505***	1,363.687***	1,559.374***
Note:						*p<0.1; **p<0.05; ***p<0.01

Comparing our previous regression results from table 5.1 (collumn 2 in table 5.3) brings some interesting observations. The significance of some variables as well as their magnitude changes when an interaction variable is added to the regression. For example, the variable *motorway* is no longer significant in models 3,4 and 5. Also, the interaction variable of *soc* and *motorways* is surprisingly not significant, as the impact of motorways was expected to be pivotal for post-socialist countries It is however larger by 0.029 points.

By comparison of R-squared and significance of individual variables, our preferred model is the regression number 6, where all but one variables are significant and the model has the highest R-squared. i.e. the following model:

$$\log(gdp_{it}) = a_i + b_1 \log(capital_{it}) + b_3 \log(motorway_{it}) + b_4 \log(road_{it}) + b_5 \log(rail_{it}) + b_6 \log(soc_{it} * rail_{it}) + b_7 empl_{it} + b_6 soc_i + u_{it} \tag{5.1}$$

The above mentioned, model has been calculated using the heteroskedasticity robust covariance matrix, similarly to regressions in table 5.1. The findings show that indicators of motorways and railways have a positive and significant coefficient at least at the 5% significance level. Here, we can therefore conclude that the importance of motorway infrastructure per capita in both post-socialist and western countries is positive. The coefficient of capital is also very high and importantly significant, this confirms the theory of public capital infrastructure effect on the levels of economic output by Aschauer (1989).

Interestingly, the direction of the relationship of the railways variable changes in model 6. The elasticity is negative and significant. In other words, any additions to rail infrastructure capital have a negative impact on the GDP. Railway infrastructure in most European, specifically Eastern-European countries, is outdated and inefficient according to Lenz *et al.* (2019), therefore this might be the reason behind our results. Our findings are in conformity with what was found by Lenz *et al.* (2019), who reported the elasticity of -14.77, even though in our case it is much lower.

The road coefficient is not significant in any of our models, which is also unexpected. Both Lenz *et al.* (2019) and Canning & Pedroni (2008) found that GDP is positively influenced by the factor of roads. Our resulting elasticities are positive but inconclusive due to low significance of the results.

Out of all interactions with the dummy variable only the $\log(soc_{it} * rail_{it})$ coefficient is significantly positive. This finding is in compliance with our descriptive statistics, where we found that the average length of railways per capita is more than double for post-socialist states. The reason behind the general railway coefficient and the interaction railway coefficient being totally opposite in magnitude, draws the need for investment in railway infrastructure, specifically its efficiency and reliability in eastern countries.

Similarly to the the regression in column two, the coefficient of employment is significant and positive, which confirms our claims for the control variable. Moreover, the employment variable is an index, it can be interpreted as a one percent increase in employment increasing GDP per capita by 0.021 percent. The positive relationship between employment and GDP further confirms the research done by Gilbert (1973), however our elasticity is not that high, compared to results from Gilbert (1973).

Similarly, to the results from table 5.1, the dummy variable *soc* is significantly high the influence of *soc* is unanticipatedly important in the model findings.

6 Conclusion

The role of transport infrastructure in economic growth has been discussed in many studies. Most find significant results when analyzing public transportation capital, the length of roads and railways or the positive causal relationship between transport infrastructure investments and growth of the economy. This thesis looked at the relationship and analyzed empirical evidence.

Literature review summarised relevant studies on this topic, indicated historical overview of individual approaches to measurement and presented a comparison between individual undertaken methods for modeling. Based on the research the production function method was selected as the best suited method for our sample and available data.

The main aim of this thesis was to test the hypothesis that transportation capital affects the economic growth in EU countries by taking into account a combination of variables set to determine the dynamics between transport and economic growth. This thesis further set the objective of analyze the difference in impact between two groups, those under the historic membership in the Warsaw pact treaty (from 1955 to 1991) and those under NATO influence. A production function approach was applied in the analysis and the results show positive impact of motorways and railways on the growth of GDP per capita in both groups combined.

This study utilized data on 27 EU member states for the period 1995 to 2017 for the total length of railways, motorways, roads, employment, GDP in PPS and the value of capital in per capita measures. Using three panel regression estimators (P.O.L.S, R.E. and F.E.), a simple model for each method was estimated with significant results for capital, motorways and employment coefficients on levels of GDP per capita. The R.E. model was determined to be the most reliable based on the Hausman test for endogeneity.

Further, interactions with the dummy variable for countries under the historical influence of Warsaw pact were deployed. The regression results showed a significant positive impact of railway infrastructure in post-socialist states with the coefficient of 0.172, however the overall impact on the whole dataset resulted to be negative with elasticity of -0.161. All models showed high rates of R-squared, which suggest low variance of the explanatory variables on the dependent variable.

To conclude, significant positive results of motorways, and capital generally correspond to previous studies by Aschauer (1989), Comission (2014) or Canning & Pedroni (2008). The magnitude of relationship was however found to be smaller in comparison. Similarly to Lenz *et al.* (2019), the coefficient of railway infrastructure was found to be negative.

Furthermore, the analysis of the relationship can be expended via a VAR model estimation to include time lags and observe wether changes in transport infrastructure capital influence future values of GDP.

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