ERASMUS UNIVERSITY ROTTERDAM

Erasmus School of Economics

Master Thesis (Urban, Port and transport economics)

Economic impact of transport corridors on regional level

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Date final version: 19.12.2018

Summary

The purpose of this thesis is to find the effect of transport corridors on regional level. Transport, being a derived demand, plays a significant role in facilitating global traded and enhancing regional cohesion within European Union. As volume of the international trade is increasing, so does the role of well-functioning and available transport networks or corridors in the economy increases. European Union, and its member states, keep investing on significant amount of money in enhancing transport corridors and it is expected, that these investments will increase competitiveness and productivity of firms, as well as total well-being of citizens. We aim to test the impact of transport corridors on regional level (EU-28 NUTS3 regions) by collecting the data on corridors location (core network corridors as defined by EC) and various economic indicators, and performing appropriate statistical analysis.

In the first chapter we analysed the context of transport in trade and derived main question of the thesis. In second chapter, we provide literature review, as well as operationalize main terms to be used in study. In this chapter we also derive hypothesis to be tested in order to answer our research question. In third chapter we collected the relevant data, both geographical and economic, and lay out the methodology to be used in subsequent analysis. In fourth chapter we carry out statistical analysis (random effects model with clustered option in order to account for heteroscedasticity and autocorrelation) and provide discussion on the results. In the last chapter, the conclusions are given.

Our empirical results indicate that regions with transport corridors bordering regions) have better employment indicators and higher economic output, measured in the gross value-added. Our findings support the previous research done on the subject. Future research should expand the time span of the study and its scope, examining it on more detailed level.

Summary (Latvian)

Šī maģistra darba mērķis ir izpētīt kāda ir transport koridoru ietekme reģionālā līmenī. Transportam, kas ir atvasināts pieprasījums, ir nozīmīga loma starptautiskās tirdzniecības veicināšanā un reģionālās kohēzijas nodrošināšanai Eiropas Savienībā. Pieaugot starptautiskās tirdzniecības apjomam, pieaug arī labi funkcionējošu un pieejamo transporta tīklu nozīme ekonomikā. Eiropas Savienība, kā arī tās dalībvalstis, turpina investēt nozīmīgus līdzekļus transporta koridoru uzlabošanai un tiek sagaidīts, ka šīs investīcijas uzlabos uzņēmumu konkurētspēju un produktivitāti, kā arī iedzīvotāju labklājību. Mēs testējam transporta koridoru reģionālo ietekmi (NUTS3 reģionu līmenī EU-28 valstīs) apkopojot datus par koridoru atrašanās vietu (pamattīkla koridori *core network corridors*, atbilstoši EK noteiktajam) un dažādiem ekonomiskajiem indikatoriem, un veicot šo datu statistisko analīzi.

Pirmajā nodaļā tiek veikta transporta konteksta analīze tirdzniecībā un tiek atvasināts pētījuma pamatjautājums. Otrajā nodaļā tiek veikts literatūras izvērtējums, kā arī operacionalizēti galvenie jēdzieni, kas tiks izmantoti darbā. Šajā nodaļā arī tiek izstrādātās hipotēzes, kuras tiks testētas, lai sniegtu atbildi uz pamatjautājumu. Trešajā nodaļā mēs apkopojam nepieciešamos datus, kā ģeogrāfiskos, tā arī ekonomiskos un piedāvājam metodoloģisko pieeju turpmākās analīzes veikšanai. Ceturtajā nodaļā mēs veicam datu statistisko analīzi (nejaušas ietekmes modelis ar klāstera opciju, autokorelācijas un heteroskedastitātes kontrolei) un diskutējam par rezultātiem. Pēdējā nodaļā tiek izdarīti secinājumi.

Darba empīriskie rezultāti liecina, ka reģioniem ar transporta koridoriem (kā arī reģioniem, kas ar tiem robežojas) ir labāki nodarbinātības un saimnieciskās darbības rādītāji, ja tos mēra bruto pievienotajā vērtībā. Mūsu konstatējumi ir atbilstoši iepriekšējiem pētījumiem šajā jomā. Turpmākajiem pētījumiem būtu jābūt vērstiem uz analīzi par ilgāku laika posmu, kā arī lielāku detalizācijas pakāpi.

Summary (Russian)

Цель данной работы – определить эффект транспортных коридоров на региональном уровне. Транспорт, как производный спрос, играет существенную роль в способствование международной торговле и увеличении региональной сплочённости. При постоянном росте объёма международной торговли, также увеличивается значимость хорошо функционирующих и доступных транспортных коридоров в экономике. Европейский Союз, а также страны участники, продолжают вкладывать существенные средства в развитие транспортных коридоров, ожидается, что данные вложения увеличат конкурентоспособность и продуктивность предприятий, а также благополучие жителей. Мы тестируем влияние транспортных коридоров на региональном уровне (NUTS3 регионы стран участников ЕС) используя данные о местонахождении коридоров (основные транспортные коридоры в соответствии с классификацией ЕС) и разными экономическими индикаторами, производя статистический анализ.

В первой главе производится анализ транспорта в торговле, а также выявляется основной вопрос тезиса. Во второй главе следует изучение литературы, утверждаются главные термины данной работы, а также выдвигаются гипотезы для проверки основного вопроса. В третей главе производится сбор данных, как географических, так и экономических и предлагается методология для последующего анализа. В четвёртой главе осуществляется статический анализ (метод случайных эффектов и с опцией кластера), а также обсуждаются результаты. В заключительной главе проведены заключения.

Эмпирические результаты показывают, что регионы которые включают в себя транспортные коридоры а также регионы которые с ними граничат, имеют более высокие показатели занятости и экономической выработки, если измерять в валовой добавленной стоимости. Наши результаты совпадают с предыдущими исследованиями. Будущие исследование должны быть ориентированы на более долгий промежуток исследования, а также более глубокую детализацию.

Contents

1. Introduction

1.1. Background

European Union is one of the most economically developed regions in the world, with GDP per capita of 33.715 USD dollars in 2017 (World Bank, 2018), only North America has higher GDP per capita (approximately 58.070 USD). As a consequence, EU accounts for second largest portion of global trade, reaching 14.8% of national imports in world trade and 15.7% in national exports (Eurostat, 2018). Top 10 trading partners of EU account more than 60% of total trade volume and reaching over than 2.3 trillion euros of annual trade in 2017 (European Commission, 2018).

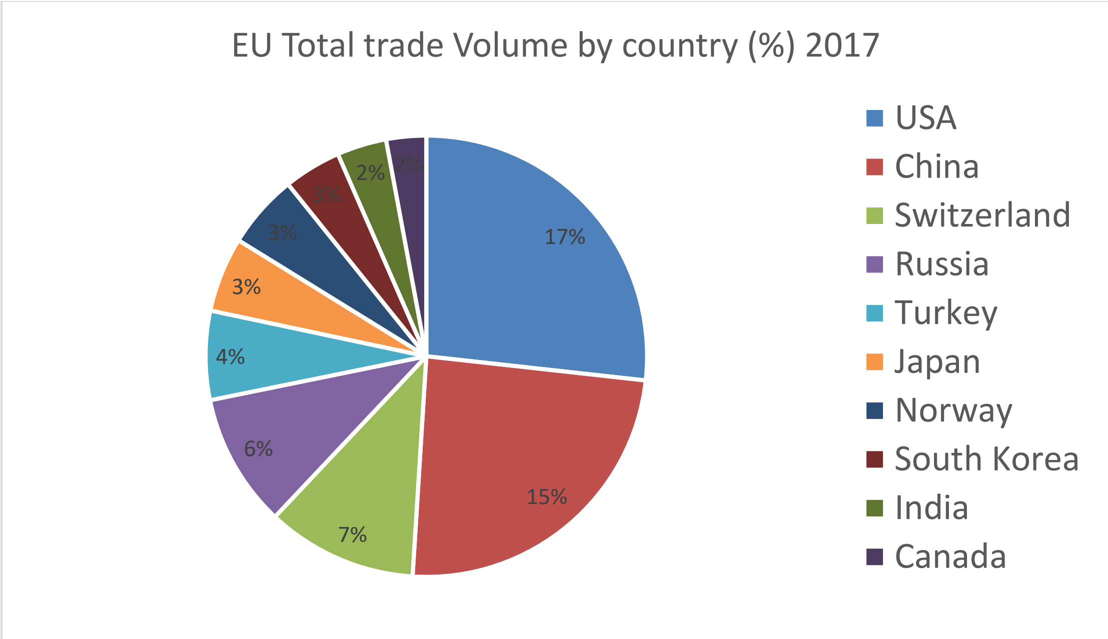


Figure 1 EU Total Trade Volume by country (%), 2017

As it can be seen from Figure 1 EU Total Trade Volume by country (%), 201, USA and China are topping the list with 17% and 15% of the total trade respectively, followed by Switzerland (7%), Russia (6%), Turkey (4%), , Japan (3%), Norway (3%), South Korea (3%), India (2%) and Canada (2%). According to OECD data, exports from EU 28 countries has roughly doubled since 2000, reaching total volume of almost 8 300 billion USD in 2016 compared to 4 500 billion USD in 2000 (OECD, 2018). Similarly, imports have almost doubled, reaching 7 813 billion USD in 2016 (OECD, 2018).

Such relatively high amount of global trade between EU and its partners means that need for transport services should also be high, since transport is a derived demand and it is as a result of the trade activities (De Palma, Lindsey, Quinet, & Vickerman, 2011). Goods have to be transported both to and fro from EU, ranging from dry and liquid bulks, like oil, agriculture and raw materials, as well as containers with finished and intermediate goods. For policy planning purposes and in order to boost development, create new jobs and establish common market. EU has defined an extensive trans-European transport network (TEN-T) which includes the major of transportation (rail, road, seaways and ports, airways) as well as type of transport (freight and passengers) (EU Parliament and EU Council, 2015). Although, the main purpose of this policy is to remove bottlenecks that already exist and foster realisation of EU economic potential, it is also aimed at boosting facilitation of trade with third countries that share common border and are vital for EU economic growth (*ibid.*).

According to Eurostat data (Eurostat, 2018) most of the goods transported to and fro from EU are handled via its ports, total volume of seaborne goods exceeds 3800 million tonnes in 2016, an increase of more than 11% since 2009. If we look at individual member countries, most of these countries shows an increase in this indicator, ranging from 1% increase for Latvia to 38% for Portugal. Only 5 countries have shown decrease in total volume of goods handled in ports– Estonia, France, Croatia, Italy and United Kingdom (*ibid.*).

Most of the inland freight cargo in EU in 2016 were transported by roads (76.4%), followed by railways (17.4%) and inland waterways (6.2%) (reference). Trends of modal split over time is relatively stable, with road freight being dominant reaching almost 80%, more details on modal split over the time can be seen in Figure 2.

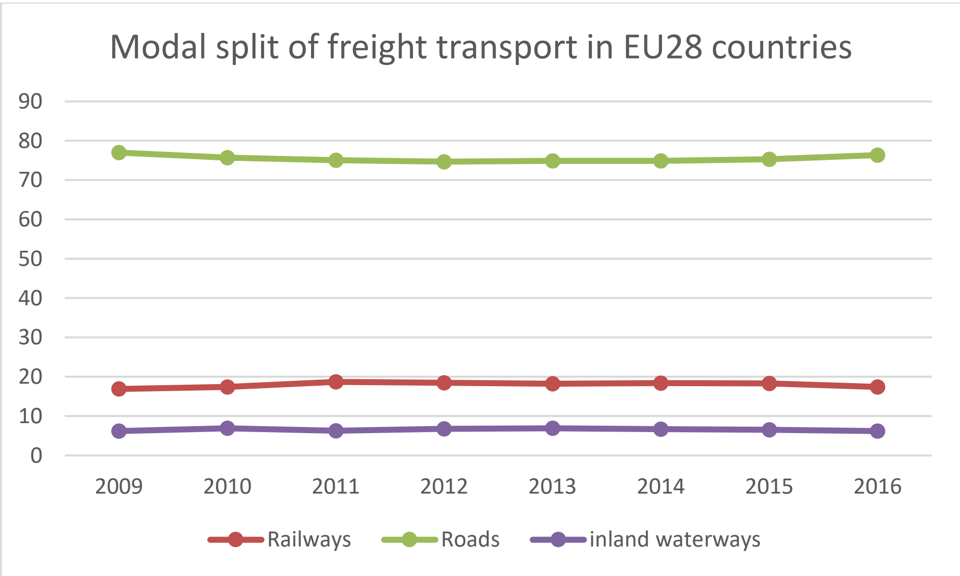


Figure 2 Modal split of freight transport in EU28 countries (source: Eurostat)

Above are the mentioned numbers that shows that EU trade with its partners is increasing over time, position of countries varies over time, and the trends in development of individual transport modes are relatively stable.

Shippers and shipping companies have made choices to stretch beyond one transport mode and a single country, it is a dynamic process which involves multiple variables, like time, costs, convenience of bureaucratic procedures and so on. The constant push of EU for increased competition in the transport sector, e.g. liberalisation of road, rail and maritime sector in last decades, has not only open new markets and benefited stakeholders, but it has also forced national governments to adjust their policies to tackle new challenges (European Commission, 2011). We can observe competition not only on firm level, but more and more on national and even regional level. Neighbouring countries are investing in joint projects (Lyon-Turin tunnel, Rail Baltic project, etc.). In order to effectively plan national policy, it has to be integrated on multiple levels, and it has to take in to an account intended actions of other regional players and still might not achieve the desired outcome. Overall competition has extended from national level to level where all elements of the supply chain have to be planned and executed properly on pan-European scale, involving multiple transport modes and many countries. Core transport corridors are being extended, where cargo flows gross number of countries and therefore require adequate planning and action from number of partners, including local society. The Commission expects that public investment of 1% of the GDP in transport infrastructure projects will lead to 1.5% increase in GDP over four years, yet they also acknowledge that these projects come at cost of negative external effects, like accidents, GHG emissions, air pollution and other (European Comission, 2018). Since such projects demands a large-scale investments, including EU, national and private financing, and are aimed to benefit the society as a whole, one question has to be answered – how does it affect the regions and where are these corridors located?

1.2. Thesis questions

Countries across the globe are constantly investing in the improvement of transport infrastructure, expecting that it will boost economic development and wellbeing of their citizens. Total amount of cargo transported is increasing, in line with the economic growth, and more complex transport networks are being established. Yet this comes at cost for all involved parties. Therefore, the main question of this thesis is as following: what is the impact of transport corridors on regional level?

In order to find an answer to this question, some following sub-questions have to be answered:

- What is a transport corridor, how it can be defined?
- What is the definition and measurement of economic impact of transport corridors?
- What is the impact of transport corridors on regions in which they are located?
- What is the impact of transport corridors on neighbouring regions?

1.3. Research approach

Proposed framework of this thesis is illustrated in the Figure 3. It represents a typical quantitative research methodology with deductive approach, the first step is to analyse existing literature, build a sufficient knowledge base on the subject and its possible limitations. As a result, several hypotheses should be proposed. Step 2 is collection of available data on the subject form various sources and merging it in to one data set. Step 3 includes quantitative analysis of the data set and testing of the hypothesis. Finally, step 4 provides conclusions based on the statistical analysis performed in previous step with regard to hypothesis.

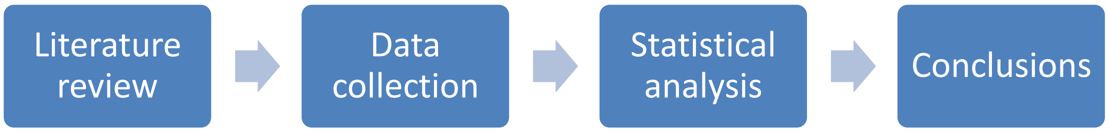


Figure 3 Thesis framework

2. Literature review

In this section, review of existing literature that is relevant to the subject will be conducted, proper definitions of terms that are necessary to carry out the research will be proposed. Confirmation and inspiration for chosen methodology will be provided.

In section 2.1 we will review existing definitions of the term *transport corridor* and propose definition that we will use in this research. Next, in section 2.2, term *economic impact* and its application to our research will be analysed, and, based on the review, thesis hypothesis will be proposed. Finally, in section 2.3 analyses of the indicators to be used will be conducted.

2.1. Transport corridor

Since main goal of this thesis is to evaluate economic impact of transport corridors, it is necessary to define what exactly a "*transport corridor*" is. Although there are a lot of articles related to the topics or issues of *transport corridors* there is no unified definition of the term in the academic literature. In her article Poletan Jugovič (2006) analyses inclusion of Croatia in Pan-European transport corridors, she defines transport corridors as having following characteristics:

> *"Such corridors determine the lowest and most qualitative movement of people and commodity flows on roads, railways and inland waterways, contributing, therefore, to the multiple advantages of the territory it is positioned on* (Poletan Jugovič, 2006)*".*

Palmowski (2003) in his article which analyses a creation of new transport corridor between Gdansk and Odessa describes transport corridor as following:

> *"The corridor covers road, rail and port infrastructure with accompanying infrastructure including access roads, border crossings, cargo terminals and equipment necessary to control traffic along the corridor as well as the links with the other transport means* (Palmowski, 2003)".

More precise definition is provided by Douma and Kriz (2003) in their article on transportation corridor planning:

> *"We define a transportation corridor as a geographic area between two points, linking multiple centres, and moving people and freight. This definition includes both the transportation infrastructure (e.g., the roadbed, rails and stations) and the new and existing development that surrounds that infrastructure".*

Priemus and Zonneveld (2003) suggest that *transport corridor* can also be analysed not only from infrastructural point of view, but also adding more perspectives or axis: economic development and urbanisation. Such broader definition is also supported by Chapman *et al* (2003) in their analysis of concepts and definitions of transport corridors in England. They suggest that framework of infrastructure, networks and governance should be employed in evolution and analysis of transport corridors, rather than just infrastructure alone.

Perhaps the most widely term *transport corridor* is being used in various studies related to transport infrastructure appraisal and evaluation of different transport cost models, which not only include direct monetary costs, but also different trade-offs that are possible, e.g. time, number of movements etc. (Shaw, 2008; Konings & Ludema, 2000; De Borger, Dunkerley, & Proost, 2007).

Various government and commercial institutions also use term *transport corridor* in their work. For example, World Bank uses following definition in one of their published reports:

> "*Corridors can be defined as a collection of routes linking several economic centres, countries and ports. While some are only road transport corridors, most of them include more than one mode of transport* (Adzibgey, Kunaka, & Nahusenay Mitiku, 2007)".

Although we could not find exact definition of *transport corridor* used by European Commission term of "*core network corridors"* is widely used with following definitions:

> *"Core network corridors cover the most important long-distance flows in the core network and are intended, in particular, to improve cross-border links within the Union."*[1]

> *„Core network corridors shall be multimodal and open to the inclusion of all transport modes covered in this Regulation. They cross at least two borders and, if possible, involve at least three transport modes, including, where appropriate, motorways of the sea."*[2]

From above mentioned sources we can conclude that term transport corridor has the following main features:

1) Its main purpose is to provide improved flow of goods and passengers between various economic regions, located in one or several countries;

[1] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013R1315
[2] http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013R1315

2) It includes one or several modes of transportation;
3) It includes not only physical (roads, railways etc.), but also logical infrastructure (customs procedures, exchange of information etc.) and adherent institutional linkage.

In context of this thesis following definition of *transport corridor* is proposed:

"A *transportation corridor is a geographic area between two points, linking economic centres, and moving freight using one or more means of transportation. This includes not only the transportation infrastructure (e.g., the roadbed, rails, waterways and terminals), but also communications and supporting processes (e.g., ICT) and public bodies, such as customs and port authorities, that are involved in the process of transportation*".

As it can be seen from definition passenger transportation is excluded from this research because there are significant differences when analysing cargo and passenger movements which do not allow to carryout meaningful analysis with given resources.

Also, air cargo will not be included in this analysis. Since air cargo has significant limitations, such as size of the transported items, which makes it hard to compare it with general cargos, and also because air transport has distinct hub and spoke system unlike traditional land or sea-based transport, where we can distinguish actual corridors and different transportation alternatives, also between distribution hubs or load centres, such as ports or large urban areas.

2.2. Economic impact

In various articles economic impact is being analysed in almost every field of science, ranging from health, agriculture, tourism and so on (Weiss & Sullivan, 2001; Birkhaeuser, Evenson, & Feder, 1991; Seetanah, 2011).The main goal of such research is to study outcome of defined activity in terms of specific indicators for given geographical area or subject, yet the details and approaches differ from one industry to another. Since the goal of this thesis is to study transport industry, we will further focus on relevant examples in literature that is concerned with economic impact studies in transport sector.

There is an abundance of previous research on economic impact of transport infrastructure (Donaldson, 2018; Linneker & Spence, 1996; Melo, Graham, & Bragade-Ardao, 2013) and on various methods tells us how such impact should be evaluated (Laird, Nellthrorp, & Mackie, 2005; Beyazit, 2015). It is mainly driven by the fact, that substantial investments in transport infrastructure, that form transport corridors, are necessary and most of the time public funding is used for that purposes. Thus, different types of studies and evaluations, like cost-benefit and economic impact analysis, are being carried out in decision making process. Scholars argue that it is not enough to calculate just direct benefits (as proposed by cost-benefit analysis), but transport project appraisal process should also include wider economic impacts (further – WEI), that encompass both gross economic benefits and gross economic costs (Vickerman, 2007; Protopapas, Warner, & Morgan, 2012). This implies that evaluation of the transport project is not only done on the local level (as infrastructure node), but accounts also for wider economic and agglomeration effects, also, in outside markets, e.g. neighbouring regions or at national level (labour migration, housing markets etc.). Although it is concluded that inclusion of WEI contributes to the validity of the estimates, it comes at cost of the complexity and accuracy, which is mainly explained by lack of micro-level data (*ibid.*). Another problematic aspect of the transport appraisal methodology is correct incorporation of social impacts in to the evaluation (Geurs, Boon, & Van Wee, 2009) which often results in underestimation of actual impact of the project on various stakeholders.

The notion of agglomeration economies is particularly important in context of this thesis, since we are trying to explore effect of global transport corridors on regional level. It has been of a steady interest of researchers, how transport infrastructure impacts local areas in terms of firm productivity and location, workforce pool and population density (urbanisation), as well as other externalities (Graham, 2007). A comprehensive summary of exiting research is provided by Chatman and Noland (2011). They conclude that there is evidence of transport infrastructure contributing to productivity increase, more efficient workforce markets and overall economic activity due to reduction of generalized price of transportation and economies of scale. Yet Graham and Van Dender (2011) test the link between transport infrastructure and agglomeration effects and find the evidence rather inconclusive, debating that effect of accessibility, as an outcome of new infrastructure, is hardly found to be acting alone, it comes with other factors in play.

As mentioned before, most of the scientific articles focus not on particular project assessments, which are usually done during the planning or decision-making phase and doesn't involve much of a scientific novelty, but largely on the way how these assessments should be done in order to properly account and estimate all possible variables. Several conclusions can be derived from these previous studies:

1) The link between investments in transport infrastructure and economic activity, especially in highly developed regions, is not always clear and is subject to the debate (Snieska & Simkunaite, 2009; Bose & Haque, 2005), notably the causality between investments in infrastructure and economic activity (Button, 1998);

2) Agglomeration and network effects need to be included in the overall appraisal of transport projects (Banister & Thurstain-Goodwin, 2011; Laird, Nellthrorp, & Mackie, 2005) since new infrastructure affects the relocation of the labour and inter-firm networks on broader spatial level (Lakshmanan, 2011);
3) Double counting of the benefits is a serious issue in appraisal process, especially if it is done on various levels, e.g., micro, macro and meso (Banister & Thurstain-Goodwin, 2011) and in measuring non-transport benefits (Banister & Berechman, 2001);

These conclusions have to be taken in to an account when choosing indicators and methods for subsequent statistical analysis.

Another caption that needs to be operationalized in order to proceed with this work is the term *economic impact* itself. It is necessary in order to quantify and measure possible impact as a result of transport corridor being located (or not located) in an area of interest, as well as aiding the choice of proper indicators for the subsequent statistical analysis.

Cambridge dictionary defines *economic impact* as:

"*A financial effect that something, especially something new, has on a situation or person*" (Cambridge University Press, 2018)

Weisbrod and Weisbrod (1997) define *economic impacts:*

"*As effect on the level of economic activity in a given area that can be viewed as business output, value added, wealth, personal income or jobs*".

We can further elaborate on its properties and define more details on how economic impact can be categorised:

- Direct economic impact – direct change of production and demand due to the new infrastructure or project (Kim, Ham, & Boyce, 2002). In transport industry, such direct effects are changes in user costs and in the external costs of transportation (Wangsness, Rødseth, & Hansen, 2017). These include costs and benefits to directly involved parties (owners, users) such as investments, usage costs and revenues, as well as other benefits, e.g. time reduction, for freight and people transportation.
- Indirect economic impact – a change in other sectors by implementation of a project (Geurs, Boon, & Van Wee, 2009). Typically, these are benefits that are passed on through markets to producers and consumers in other sectors and include costs and benefits of the transport improvement (Elhorst & Oosterhaven, 2008);

Third category, namely, *induced economic impact* which is a change in spending or sales within the region of the income earned due to the new infrastructure or project (Weisbrod & Weisbrod, 1997) is often mentioned in theory, but is rarely found in articles related to the transport industry. This might be explained by the above-mentioned need to include WEIs in evaluation of transport projects, since their goal is quite similar – to look for the effects that are outside direct or indirect impact, but include variety of other factors, quite often outside given region and markets.

It is important to note that in order for the review to be complete it is necessary to also mention the negative externalities - different effects from activity that are not reflected in market prices (Organisation for Economic Co-Operation and Development, 2018). In context of transport sector, most common negative externalities are congestions, accidents, road damage and environmental pollution (European Comission, 2018). Yet there are some difficulties in conceptualizing, these are externalities in terms of *economic impact*, namely – the above mentioned issues do not carry direct economic value. In order for them to be operationalized we would have to apply some form of monetizing in to comparable currency values. Think of a SO2 or NOx pollution, what is the monetary value of exposure of general public (or even more – business entities) to this type of pollutants? There are multiple reports and studies that deal with this subject (see OECD (2014; 2016) for examples), yet it is based on various assumptions of the economic impact of health hazards from transportation. Including such proxies would add additional degree of uncertainty to our study, therefore we leave this aspect outside the scope of our thesis.

In order to properly examine WEIs impact on regional level, indicators to be used in this study should be available on lower regional level (NUTS-3), since it is necessary to compare data not only on particular region, but also on its adjacent territories.

As a result, *economic impact is defined* in context of this thesis, and it is being proposed:

"*An effect that location of transport corridor has on the region where it is placed, as well as its adjacent regions, in terms of changes in economic activity*".

Based on the abovementioned review, we can theorize that there should be correlation between transport corridors and various economic indicators, like output, employment and urban density. What is of our interest, is to test this in broader scale (pan-European), and evaluate if this relationship is captured only in particular regions with transport corridors and in their adjacent regions:

No.	Hypothesis	Effect on regions with corridor	Effect on adjacent regions
H1.	Regions with transport corridors have higher employment indicators compared to other regions	Positive	Positive
H2	Regions with transport corridors have higher output compared to other regions	Positive	Positive

Table 1 Thesis hypothesis

When discussing the scale effect of the transport corridors or the proximity of the transport corridor impact, most common approach is to use administrative borders as a unit of measurement, since socioeconomic information is available on lower administrative unit level (NUTS3), e.g. Guttierez *et al* (2011). There are studies that perform analysis on lower regional level (NUTS5 or municipalities), see Holl (2004; 2007) and Ribeiro *et al* (2010), which allow for more granularity, yet it comes at the cost of data preparation and availability from local sources (regional accounts by local public bodies). Since our focus in on the pan-European scale, we will not delve in to such details.

Most of the studies focus on one mode of transport (roads), not the concept of corridor as a whole and use changes in accessibility or investments in transport infrastructure as a proxy. In line with previous conclusions, authors suggest that attention has to be paid to include agglomeration and urbanisation effect in the model, to control for exogenous changes of the indicators (Melo, Graham, & Bragade-Ardao, 2013). Previous studies demonstrate that there are spatial spillover effects (Rokicki & Stepniak, 2018; Berechman, Ozmen, & Ozbay, 2006), meaning that transport infrastructure can attract economic activity on expense of adjacent regions and that the scale of the region included in the model is important to detect such effects (decay of the spillover over longer distances).

2.3. Indicators

Choice of particular indicators is driven by hypothesis that needs to be tested, and determined by data availability, especially if we look on detailed regional level (NUTS3 in our case). We will continue with analysis of hypothesis statements and review of potential indicators that could be employed in study, and identify potential source of suitable data.

When choosing indicators, we assume that there is a link between transport corridor location and selected economic indicators. Since our main goal is to determine if *transport corridors* have *economic impact* on the regional level it will be necessary to analyse particular indicators for the whole area of study (European Union) compared to particular regions (ones with transport corridors located in them and adjacent regions).

H1 Regions with transport corridors have higher employment indicators compared to regions without transport corridors

We can theorize that access to a well-functioning transport network will lead to economic activity shifting closer to the transport corridors in order to reap potential benefits of access to such transport arteries (e.g., lower transportation costs for supplies and end-products, more efficient logistics). As a result, more people will be employed in regions around such corridors, hence the better employment indicators. EUROSTAT provides one indicator that corresponds to this hypothesis: employment (thousand persons) by NUTS 3 regions (abbreviation: nama_10r_3empers). It accounts for total number of employed persons in given statistical territorial in a given year (data available from 2000). Thus, it would also allow to track changes over time. It would correspond to direct (people employed in the construction of transport corridors or shipment of the goods using these corridors) and indirect (increased economic activity not related to the shipment or construction) economic impact of transport corridors. In the perfect scenario, we would like to use data on unemployment rather than employment, since it would more precisely reflect our area of interest. The main difference is the inclusion of people who are not actively looking for the job (i.e., students, family members taking care of small children etc.) in employment indicator, where unemployment accounts only for those, who are actively looking for the job (Shishkin, 1976). One way to circumvent this is to use employment-to-population ratio, if there is suitable data to construct it. According to International Labour Organisation (2018) this indicator is constructed by dividing total number of persons employed with working age population. Its main limitations are associated with variations in data collection frequency which can lead to bias due to seasonality and computation of average values (more frequent data collection leads to better accuracy), and definition for the employment and population figures to be included, for example, different upper and lower bounds for labour force activity and whether to include members of the armed forces. In terms of this research, another possible constraint of using employment to population ratio is the fact that it will include the working force migration between nearby regions and therefore would not allow to properly account for possible impact on adjacent regions. This will happen, if employment to population ratio will take value higher than 1, meaning more people are being employed in the region than there is registered working age population and, most likely, they are coming from nearby regions (implying relatively short everyday trips to work and back to their registered address). These assumptions have to be tested when constructing models in order to determine which of the indicators provide better fit.

H2 Regions with transport corridors have higher output compared to other regions

In line with previous conclusions, we can speculate that higher economic activity nearby transport corridors will lead to higher competition, hence also output due to the better workforce pool, spill-over effects and increased competition (the effect of agglomeration economies has been discussed in previous section). EUROSTAT collects two possible indicators – gross domestic product (GDP) at current market prices and Gross value added at basic prices. GDP refers to value of all services and products being produced in the region. It is one of the most commonly used indicator in economics (Anderson, 1993), yet due to the way it is being measured it might not capture actual value of the goods and services that are being produced in the particular location, but can be accounted just because of the company has registered in particular region when all the economic activity is taking place somewhere else. In comparison, gross value-added measures the value added for services or products in an area or industry taking in to account that final goods or products can be assembled with intermediaries of significant value (Aparaschivei, Vasilescu, & Cataniciu, 2011). In context of this thesis and particular hypothesis, we are more inclined to use GVA as an indicator, as it would more precisely reflect on economic activity that takes place in the region of study. Nevertheless, we can include GDP as an additional indicator to compare the model outcomes, if necessary.

As a result, we provide following indicators for testing of our hypothesis:

No.	Hypothesis	Indicator	Source
H1	Regions with transport corridors have higher employment indicators compared to other regions	Nama_10r_3empers	EUROSTAT
H2	Regions with transport corridors have higher output compared to other regions	Nama_10r_3gva	EUROSTAT

Table 2 List of indicators

Following the previous discussion on need to control for agglomeration effect, we suggest that population density (Eurostat indicator: demo_r_d3dens) and total population (Eurostat indicator: demo_r_pjanaggr3) should be included in the model and results of models with and without such control variable should be compared. Our previous review of literature suggests that in the long run, agglomeration effect might be the impact of transport corridors, since more efficient logistics, improvement of the accessibility to both work-force pool and markets in general, can concentrate economic activity closer to the transport corridors, albeit the evidence on causality of transport investments and economic development is not always conclusive (Button, 1998). Therefore, it makes sense to control for the agglomeration economics in the short term, as it is the case of our study.

3. Data and methodology

In this chapter we will provide the overview of statistical analysis of the economic impact of transport corridors.

In the first sub-chapter, we will analyse the GIS data set and describe necessary manipulations to extract required properties for further analysis.

In the second sub-chapter, we will analyse available indicators to determine their suitability for subsequent statistical analysis.

In the third sub-chapter, we will discuss the model that is going to be used in the analysis based on our data and hypothesis.

In the fourth sub-chapter, we will outline the results of statistical analysis.

3.1. GIS data

In order to carry out the intended analysis (compare regions with transport corridor and without it) we need to combine data on European regions at NUTS3 level and transport corridors. The easiest way to accomplish it is to plot information with transport corridors location and Europe's NUTS3 regions in Geographical information system (GIS), for this purpose we used ArcGIS package. Information on NUTS3 regions in suitable format (shapefile) is available online (European Commission, 2018). In total there are 1342 NUTS3 regions in Europe (see Picture 1 Map of Europe NUTS3 regions).

Picture 1 Map of Europe NUTS3 regions

In 2013 EC has defined 9 core TEN-T transport corridors (see Picture 2), namely:

1) Baltic Adriatic;
2) North Sea – Baltic;
3) Mediterranean;
4) Orient/East – Med;
5) Scandinavian – Mediterranean;
6) Rhine – Alpine;
7) Atlantic;
8) North Sea – Mediterranean;
9) Rhine – Danube.

Picture 2 Map of Europe with NUTS3 regions and core network corridors

The above mentioned corridors, as dominant cargo routes, existed well before 2013. The first attempts to establish a "master plan" to connect national networks of all transport modes date back to 1996 when European Commission developed and adopted guidelines for financial aid in the field of trans-European networks in order to facilitate economic and social cohesion between member states and achieve other key policy objectives. One of the criteria for priority projects is to eliminate bottlenecks on major routes of the trans-European network, especially for cross-border projects (European Parliament and Council, 1996). Later, decisions were focused on development of these corridors, taking in to an account the expansion of EU in 2004 and to allocate necessary funding. Though, the notion of "Core Network Corridor" was established only in 2013, the approach of pan-European transport networks is clearly visible throughout the EC policy planning documents and, most importantly, the funding decisions.

Using Core Network Corridors as a base for indicators in analysis poses some limitations, especially if considering that national investments might not be in line with trans-European network development plan and are aimed at removing local bottlenecks or strengthening local nodes. Nevertheless, the share scale of trans-European network investments made since 1996 should allow to accept these limitations in favour of more centralized approach with clear geographical scope.

Information on TEN-T core network transport corridors location in suitable format was provided by DG MOVE upon request and signing of NDA.

Provided shapefile contains six layers (roads, railways, inland waterways, ports, airports and railroad terminals). There are multiple additional fields to each of this feature class, which allows for more detailed analysis to be performed if necessary, e.g. field "Corridors" describes which particular corridor is the feature part of, as well as the status of the element ("Completed", "To be completed", "Study" etc.).

We combine all 5 layers (excluding airports, as it is not part of our study) with NUTS3 shapefile (using "Spatial Join" tool in ArcGIS) and as a result we derive a full list of NUTS3 Europe regions (polygons) with additional fields containing values for given features indicating if region has roads, railways, inland waterways, ports or railroad terminals which are part of TEN-T core network corridors. Some of the "Ports" points were located in the water, so we have to adjust them to match "Region" (polygon). We further exclude all elements, that are not "Completed", don't belong to "Core network" and in case of railways, also exclude ones that are only "Passenger" (as it is outside the scope of this thesis).

We also add one variable "Corridor" which takes value "1" if there is at least one of the features and "0" if it doesn't contain any. In total there are 827 regions with at least one corridor element.

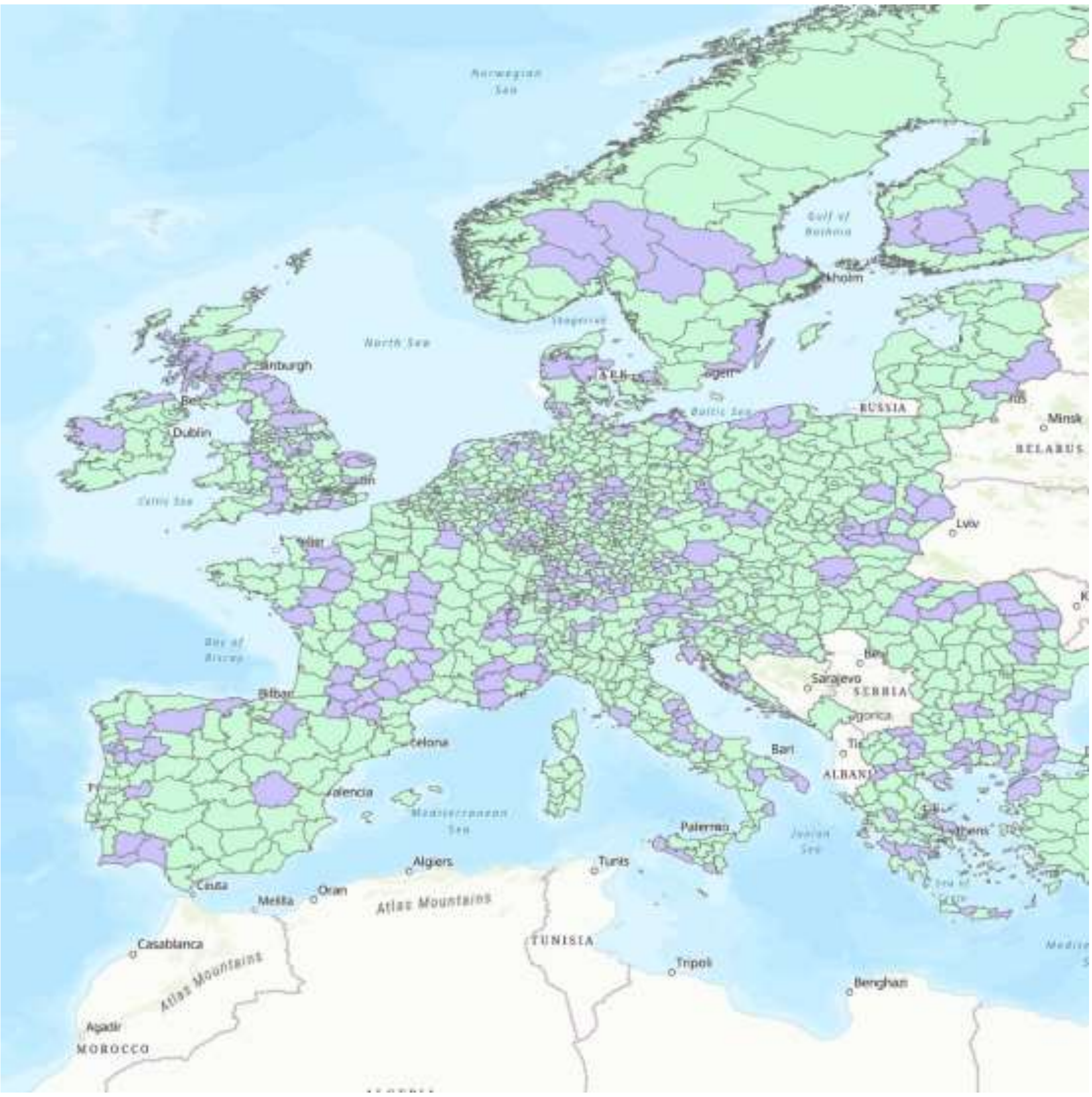
Table 3 displays number of NUTS3 regions containing TEN-T core network elements:

Feature type	**Railways**	**Inland waterways**	**Railroad terminals**	**Roads**	**Ports**
Count of NUTS3 regions	646	284	99	573	129

Table 3 NUTS3 regions with different corridor elements

In order to derive adjacent regions, we use "Select by location" by adding all layers to one ("Add to current selection") and finally choosing relationship type "Boundary touches" to choose all regions that have a border with TEN-T core transport network polygons.

Picture 3 displays NUTS3 regions that are adjacent to regions with TEN-T core network elements in them, in total there are 304 such regions in EU.



Picture 3 Map of NUTS3 regions bordering corridor regions

Afterwards, all the combined data is exported to Excel, cleaned up (removed duplicates) and prepared for import to statistical package tool as data file.

3.2. Data set

We further proceed with data collection from Eurostat according to our results from literature analysis.

We start with employment data, where we have a cross-sectional time series or panel data on NUTS3 level for variable employment in thousands, given for years 2007 till 2016 available from EUROSTAT (Eurostat, 2018a). Upon examination, we can see that the data set has missing values for 2016, so we narrow down data set for 2007 till 2015 and filter to include only EU-28 countries.

Correspondingly, we have full data set for 28 countries for all requested years. The same procedure is applied for gross value-added (Eurostat, 2018b), population density (Eurostat, 2018c) and total population (Eurostat, 2018d).

In order to construct employment to population ratio, we chose population aged from 15-64 on NUTS3 level (variable *workpop*) and generate new variable (named *empop*) by dividing employment data (after multiplying it by 1000) with working age population.

Descriptive statistics of main variables can be seen in Table 4.

It indicates that there are missing values for variables “Employment” (3 observations), “Population density” (304 observations) and population data (137 observations) and since employment to population ratio is constructed using population data it has similar amount of missing observations.

Taking in to an account the large total data set (more than 12000 observations), these missing values should not represent a significant problem for statistical analysis.

Variable	Obs	Mean	Std.Dev.	Min	Max
GVA	12076	8879.358	14392.39	161.1	190000
Employment	12073	169.481	215.269	3.4	3464.7
Population density	11772	594.437	1446.123	2	21317.9
Population	11939	376000	428000	10053	6430000
Employment to population ratio	11939	.684	.215	.337	4.499

Table 4 Descriptive statistics of main variables

Histograms of these variables can be found in the Appendix 1.

As seen above, all the variables are positively skewed and are not normally distributed, with exception of employment to population ratio which is somewhat normally distributed.

Upon more detailed examination, we can see that some regions in Germany, France and Poland have missing values for population and population density, these missing values seem to be random, therefore they don’t have significant impact on our data set validity.

If we examine the range of relatively low values of employment, we can see that they correspond to certain regions of Spain (part of Canary Islands), Greece (regions located on Ionan islands) and other remote or geographically constrained regions (Austrian mountains etc.).

Similar situation is with low values for density, they are mostly for remote Northern parts of Sweden, Finland and islands of UK.
High values for employment to population ratio are for central part of London (Westminster, City of London).
We can conclude that these low and high values do not represent any additional limitations to the research or analysis.
We further proceed with correlation matrixes of dependent variables (Table 5).

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) Density	1.000								
(2) Bordering	-0.082	1.000							
(3) Corridor	0.040	-0.685	1.000						
(4) Roads	-0.034	-0.464	0.677	1.000					
(5) Railways	0.044	-0.523	0.763	0.633	1.000				
(6) Ports	0.120	-0.178	0.260	0.223	0.256	1.000			
(7) IWW	0.048	-0.284	0.414	0.122	0.163	0.241	1.000		
(8) Population	0.190	-0.140	0.189	0.271	0.242	0.341	0.035	1.000	
(9) Emppop	0.330	-0.026	0.048	-0.047	0.046	0.077	0.101	-0.023	1.000

Table 5 Matrix of correlations of independent variables

As seen above, variable “Railways”, “Roads” and “Corridor” can be considered highly correlated, with correlation ratio around 0.7. This can be explained by the dominance of roads and railroads in transport corridors physical infrastructure (railroads often being used to decrease cargo traffic from roads) and the way variable “Corridors” is constructed (it takes positive value if any of the physical infrastructure modes is present in the particular region, thus embedding the correlation).
Though it might give us some additional depth for the study, the above mentioned collinearity and complexity of interpretation of the results makes it perplexing. The relative short time span of our data should also be considered as a limitation if we would like to discuss the differences in corridor regions based on its infrastructure type.
Since our main research question is related to impact of corridors as a whole, not on the detailed scale of particular type of infrastructure, we will exclude this set of variables from further analysis.

3.3. Methodology

Appropriate statistical model is determined by our research question and available data set. Since we have panel data and we want to examine the effect of the independent variable that doesn't change over time, (transport corridor or adjacent region takes fixed, binary value throughout all periods of study) the random effects model should be applied.

In order for this method to provide consistent and reliable results, the following assumptions should hold (Greene, 2012):

1) Linearity – the regression model is linear in parameters;
2) Independence of the observations;
3) Error terms are homoscedastic and not auto correlated;
4) No perfect collinearity between independent variables;
5) Exogeneity of independent variables.

We will further discuss the underlying assumptions to see if they hold in our case, carry out appropriate tests and in case they indicate possible deviations, provide solutions to the particular issue.

Linearity of the model implies that dependent variable is formulated as a linear function of a set of independent variables and the error term. We provide mathematical representation of our model below, but upon examining our data set, we can see that all variables to be used are indeed linear in their form, therefore we can conclude that assumption of linearity holds.

Review of the second assumption of independence of observations also is quite straightforward, we have collected extensive data set for all region of interest (EU-28 countries). Although there are some missing values, yet they are rather limited (less than 400 out of total 12000 observations) and are random in their character (missing data from source does not indicate any particular pattern). Therefore, we conclude that assumption of independence of observations also holds.

The third assumption of homoscedasticity and no autocorrelation of error term can be tested using statistical package. In order to perform these tests, we first need to set up the model, which we will do in the next sub-section.

In the case where tests indicate presence of autocorrelation and/or heteroskedasticity we will have to use cluster or robust option and report only results with robust standard errors.

The fourth assumption can be accounted by examining correlation matrix of independent variables, this allows also to test for multicollinearity which is necessary in order for random effects model to provide meaningful results as seen in the previous sub-section (see Table 5).Based on this, regression models should only include independent variables that are not highly correlated.

The last assumption of exogeneity implies that independent variables which are included in our model are not affected by other variables that are in the same model, or factors that are not captured by our model, that is, independent variables are not correlated with residuals (*ibid.*). If this assumption is violated, it can lead to biased and inconsistent estimators. In our case, economic shock, like that of economic crisis in 2009, most likely will have effect on both population (decreasing rate of birth, due to worsening economy) and employment rate (shrinkage of economy leading to lower employment), as well as other factors. We have to admit that we can't apply such a strict assumption of exogeneity in our model, therefore we have to be careful in interpretation of the results of our econometrical analysis.

We can mathematically represent our model as following:

$$Y_{ti} = c + \beta_1 F(agglomeration_{ti}) + \beta_2 Corridor_i + \beta_3 Bordering_i + e_{ti}$$

Where:

Y_{ti} – dependent variable for region *i* in period *t*;

c – constant term*;*

β_1 F(agglomeration $_{ti}$) – coefficient for function of agglomeration economics for region *i* in period *t;*

β_2 Corridor – coefficient for corridor for region *I;*

β_3 Bordering – coefficient for corridor for region *I;*

e_{ti} – error term for region *i* in period *t.*

4. Analysis

In this chapter we will produce statistical output tables and discuss the results.

4.1. Statistical analysis

In order to test our hypothesis and compare models with different variables, we will employ following step by step process (Table 6):

Model No.	**Dependent variable**	**Independent variables**
1.	Employment	Corridor Bordering
2.	Employment	Density Corridor Bordering
3.	Employment	Density Population Corridor Bordering
4.	GVA	Corridor Bordering
5.	GVA	Density Corridor Bordering
6.	GVA	Density Population Corridor Bordering
7.	GVA	Density Population Emppop Corridor Bordering

Table 6 List of statistical models

We test the first hypothesis that regions with corridors (or regions adjacent to corridors) have higher employment indicators with models 1-3.

The first model is a basic one with employment as dependent variable and two control variables (Corridor and Bordering), whereas the second and third one include controls for agglomeration economies (population and density).

Models 4 - 7 are likewise repetition of models 1-3, but with gross value-added as a dependent variable (testing the second hypothesis: regions with transport corridors or regions adjacent to transport corridors have better economic output) and additional model with employment to population ratio as a control for agglomeration economies.

We don't include employment to population ratio as a control variable when modelling effect of corridors on employment for following reasons:

- There is embedded collinearity of employment and employment to population ratio.
- If we compare two regions with similar population, region with higher employment to population ratio will have higher employment, just by simple math.
- Consequently, this will lead to misspecification of the model and therefore should be avoided.

Thus, in total we will have 7 regression outputs.

Following our discussion regarding assumptions, we first test both models for heteroscedasticity and serial correlation.

Results of the Woolridge test for autocorrelation in panel data can be seen in table below (Table 7).

Dependent variable	**F statistics**	**Probability**
Employment	F (1,1330) = 330.293	Prob > F = 0.0000
GVA	F (1,1330) = 124.184	Prob > F = 0.0000

Table 7 Results of Woolridge test for autocorrelation in panel data

In order to test for heteroscedasticity, we conduct likelihood-ratio test, corresponding results are displayed in Table 8:

Dependent variable	**Test statistics**	**Probablity**
Employment	LR chi2 (1341) = 33275.68	Prob > chi2 = 0.0000
GVA	LR chi2 (1341) = 41881.30	Prob > chi2 = 0.0000

Table 8 Likelihood-ratio test for heteroscedasticity

As seen from the test outputs above, we have to reject the null hypothesis of no autocorrelation and no heteroscedasticity for both models, therefore we will have to use clustered option for random effects regressions.

Corresponding regression tables are represented below (Table 9 and Table 10).
In order to provide better overview of the results, we have aggregated them in to nested table format for each dependent variable.

	(1) employment	(2) employment	(3) employment
Bordering	-8.603	3.173	7.709**
	(8.992)	(9.985)	(3.657)
Corridor	78.249***	81.366***	17.912***
	(11.647)	(11.648)	(3.387)
Population density		0.033***	0.019***
		(0.010)	(0.005)
Population			0.000***
			(0.000)
Employment to population ratio			
_cons	123.162***	99.138***	-11.278**
	(7.431)	(10.587)	(4.845)
Obs.	12073	11772	11772

R-squared overall	0.0355	0.1238	0.9293

Standard errors are in parenthesis

*** p<0.01, ** p<0.05, * p<0.1

Table 9 Regression results, dependent variable employment

	(4) GVA	(5) GVA	(6) GVA	(7) GVA
Bordering	-416.532	1481.431*	1370.963***	1088.405***
	(536.640)	(759.287)	(485.787)	(410.353)
Corridor	4969.605***	5472.415***	1308.154***	698.080
	(735.902)	(842.829)	(495.686)	(437.179)
Population density		5.345***	3.287***	2.703***
		(0.818)	(0.581)	(0.403)
Population			0.027***	0.028***
			(0.002)	(0.002)
Employment to population ratio				12760.402***
				(1304.290)
_cons	5918.090***	2068.095***	-4179.44***	-12645.74***
	(419.773)	(763.824)	(739.004)	(1235.464)
Obs.	12076	11770	11770	11770
R-squared	0.0310	0.1884	0.7673	0.8092

Standard errors are in parenthesis

*** p<0.01, ** p<0.05, * p<0.1

Table 10 regression results, dependent variable GVA

4.2. Discussion

In this sub-chapter we will provide discussion on our research results.

Our findings suggest that overall regions with transport corridors and regions adjacent to regions with transport corridors have better economic output and employment indicators compared to regions without such transport corridors, but this is present only when we control (at least partially), for agglomeration economies, and results differ if we consider employment to population ratio.

We further elaborate on each set of models and their main results, we start with models for employment.

Basic model without controls for agglomeration economies show that having a transport corridor is beneficial (coefficient is positive) and it is statistically significant at 1% level, yet this model has very low fit (adjusted R^2 just 0.03).

Adding population density to the model doesn't bring any changes in terms of significance of corridor or bordering, later still being statistically insignificant, but increases adjusted R^2 to 0.12.

If we further add population as an additional control for agglomeration economies, both bordering and corridor becomes statistically significant (albeit bordering only at 5% level) and both have positive coefficients. Both controls for agglomeration economies are statistically significant and have positive coefficients, this also significantly increases model fitness measured by R^2 to 0.93.

If we analyse models with GVA as dependent variable, the outcomes are somewhat similar, yet there are few differences: when controlling for density variable bordering is statistically significant at 10% level and when controlling for both density and population, it is significant at 1% (compared to 5% level in similar model for employment). The main difference is in the additional model with employment to population ratio, where variable corridor is statistically insignificant, but bordering is statistically significant at 1% level. Also, model fitness is somewhat lower with all control variables (overall R2 0.18 for model with population density, 0.77 for model with population density and total population, 0.81 for model with all three control variables for agglomeration economies).

What do those results mean in the context of our study?

We can split the interpretation of the outcome into two parts. First, if we analyse the results without taking in to an account workforce participation ratio (employment to population), our results are in line with the suggestions from previous studies. That is, having a transport corridor or being a region that is adjacent to regions with such transport corridors, will lead to better employment and higher economic output. Having a transport corridor will add almost 17 000 additional employed persons and 1.3 billion of gross-added value, other things equal. Being an adjacent region will increase employment by 7 700 and GVA of almost 1.4 billion euros, *ceteris paribus*.

We can also confirm, that agglomeration economies play significant part in those effects, as suggested by sharp increase in model fitness, and positive and statistically significant coefficients of control variables. All of this is corresponding with our theoretical findings form previous studies.

Secondly, the contradiction emerges if we look at the results with additional control variable in terms of population to employment ratio.

For economic output bordering regions can expect increase by roughly 1 billion euros, *ceteris paribus*, where corridor regions will have no statistically significant difference. This can be explained if economic value creation is located outside regions with corridors, and those bordering corridors still capture the benefits of improved logistics, inputs availability and

connection to markets via secondary road network that is not presented in core network corridors.
The empirical findings of this model that bordering regions tend to have higher gross-value added and having a corridor will have no such effect, contradicts existing literature, which strongly suggests, that economic activity is attracted by better logistics availability and other factors that are direct or indirect result of transport corridors being located in the region. Another possible explanation for such outcome might be the fact that population is correlated with dependent variable GVA, as they both depend on the size of the region. Adding the ratio of population to employment to the model basically accounts only for difference for working age population. We can conclude, that adding workforce participation ratio as a control variable indicates misspecification of the model 7, therefore it should be left out of the further interpretation.

Overall, we can conclude that our results confirm those of the previous studies. Better infrastructure, in terms of transport corridors, has positive impact on employment and economic output both for the regions with corridors and those adjacent to them. There is also a strong evidence that agglomeration economies play a significant role in both cases.

There are several limitations to our study that have to be mentioned.
Firstly, our study time span is relatively short, covering only 9 years. We can speculate that for transport infrastructure it takes more time to fully deliver lasting impact then just one decade.
Secondly, our variables for transport corridors are aggregated and static, they don't change over time, therefore some changes associated with the actual development of transport infrastructure during the study period (increased capacity, removal of existing bottlenecks etc.), might not be accounted with our framework.
This lack of variation in control variables for corridors, also affects our ability to evaluate its causality effect on economic output and employment. Also, available data provides opportunity to measure particular type of the infrastructure, which is not carried out in this study.
Thirdly, the geographic scale of our data set is rather large (NUTS3 level), previous studies suggest, that changes tend to have higher effect in shorter distances and decay as distance increases. Furthermore, we don't account for possible spatial correlation of the outcomes.
The last limitation refers to exogeneity assumption as discussed in methodology section. We can't assume strict exogeneity of our model, hence there is a risk of biased coefficients.

Future research in this field should take in to account all the above-mentioned limitations and focus on:

1) The geographical scale of the study – performing analysis on lower regional scale (below NUTS3 regions) and taking in to an account possible spatial correlation between regions of interest;
2) The type of the infrastructure – the effect of the particular type of the transport infrastructure should be also evaluated, especially taking in to an account that such data is available;
3) The type of economic activity – the results of transport infrastructure on more granulated impact indicators (type of employment and/or industry);
4) Increase time span of the study and analyse impact of changes in the transport corridors and their underlying infrastructure.

5. Conclusion

Our research question was:

What is the impact of transport corridors on regional level?

In order to find answer to this question, we derived two hypotheses and tested them using available data on EU member countries NUTS3 regional level for 9-year period:

1) Regions with transport corridors and adjacent regions have better employment indicators;
2) Regions with transport corridors and adjacent regions have better economic output.

We operationalized terms of transport corridors and economic impact, as well as studied previous research, which indicated that we should add control variables for agglomeration economies. We then collected available data and performed statistical analysis in order to evaluate the effect of core network corridors on employment and economic output, measured in gross value-added. Our empirical findings suggest that both hypotheses are confirmed. There is sufficient evidence that regions with transport corridors, and those adjacent to them tend to have higher employment and economic output.

We can conclude that transport corridors have positive impact on regional level, not only to the regions with transport corridors, but also bordering regions.

These findings support previous research done in this field.

Main limitations of our study are associated with relatively short time span, broad geographical scale of the regions under study and static assumption of transport corridors, which restrains our ability to explore causality of the transport infrastructure and their economic impact.

Further studies are needed to fully understand the economic impact of the transport corridors on regional level, extending it to more detailed level (both for type of corridors and economic impact) and longer time span.

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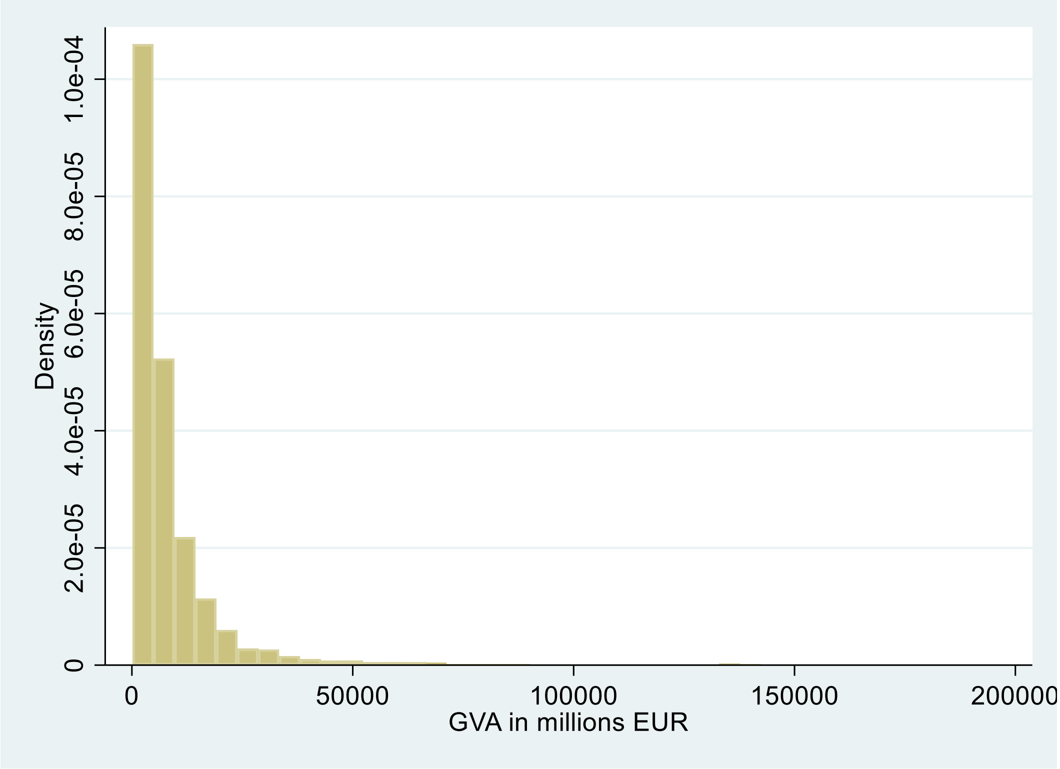
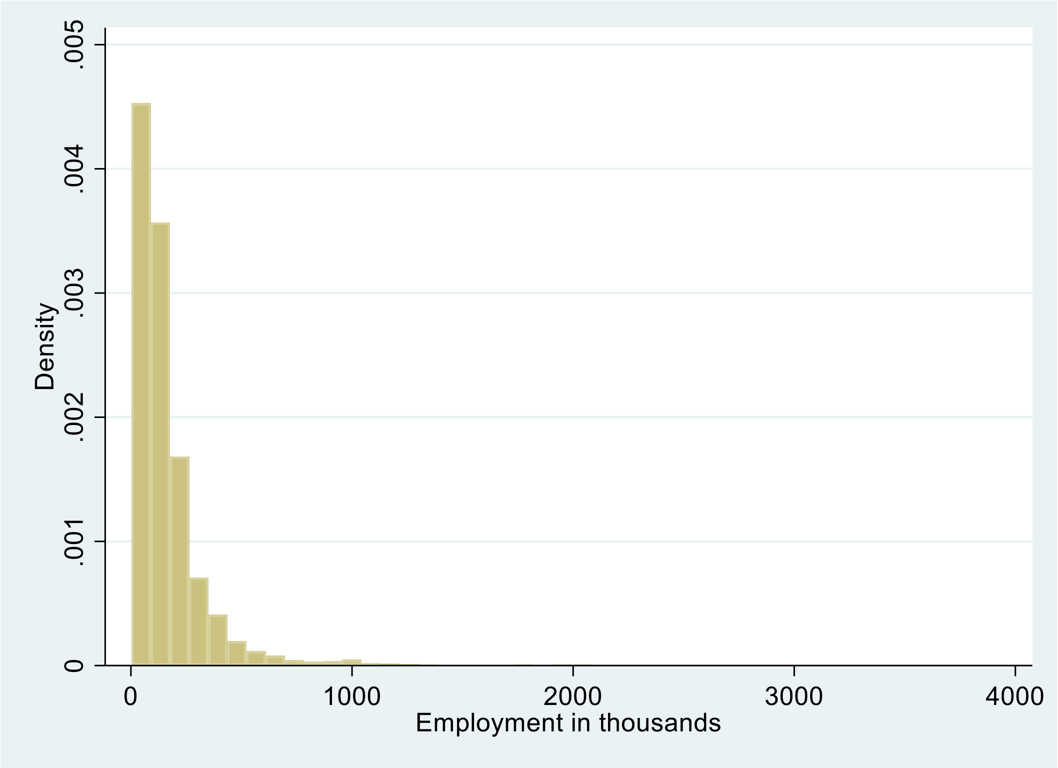
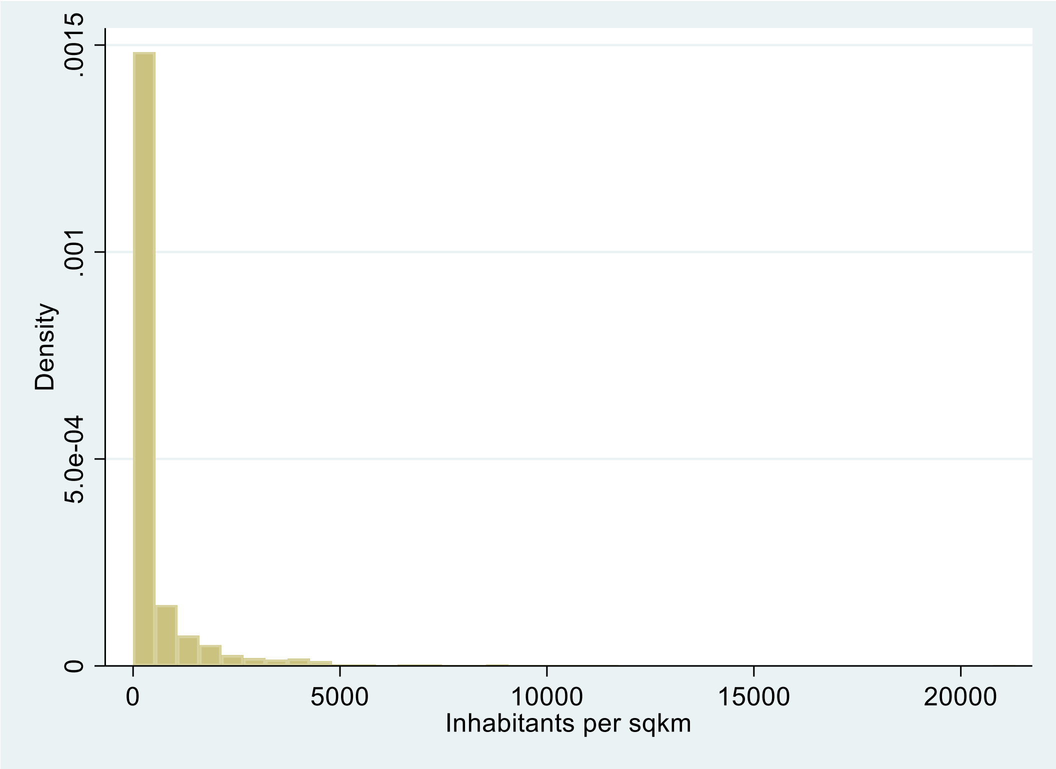
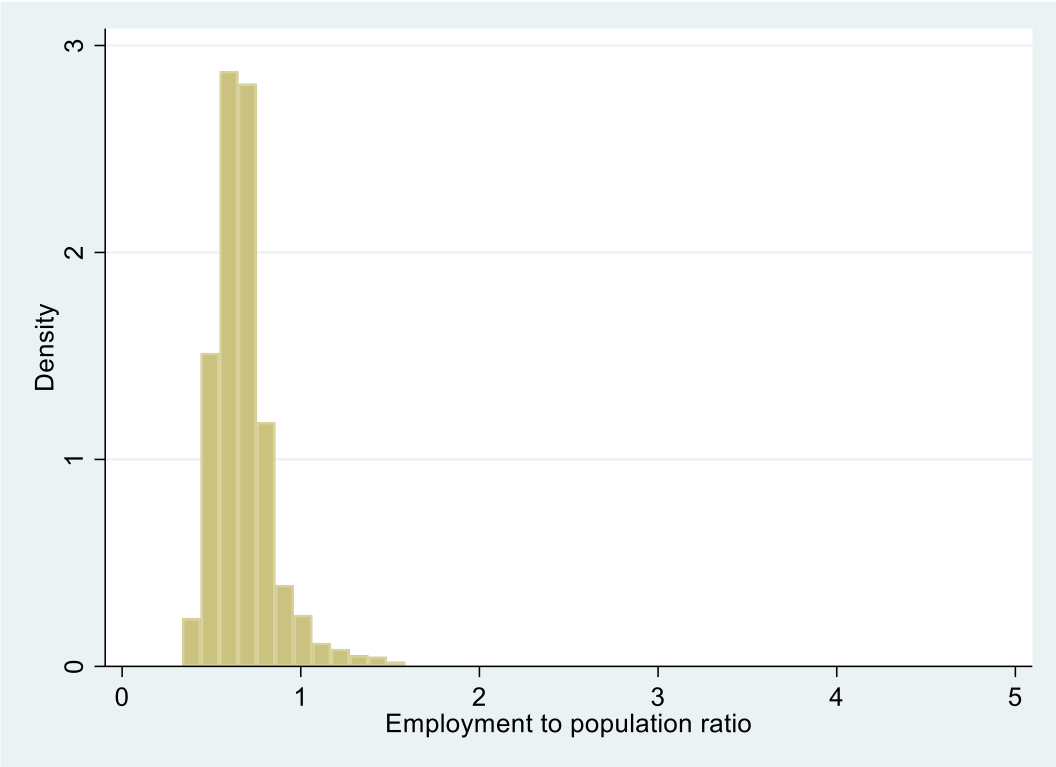
Appendix 1 Histograms of main variables



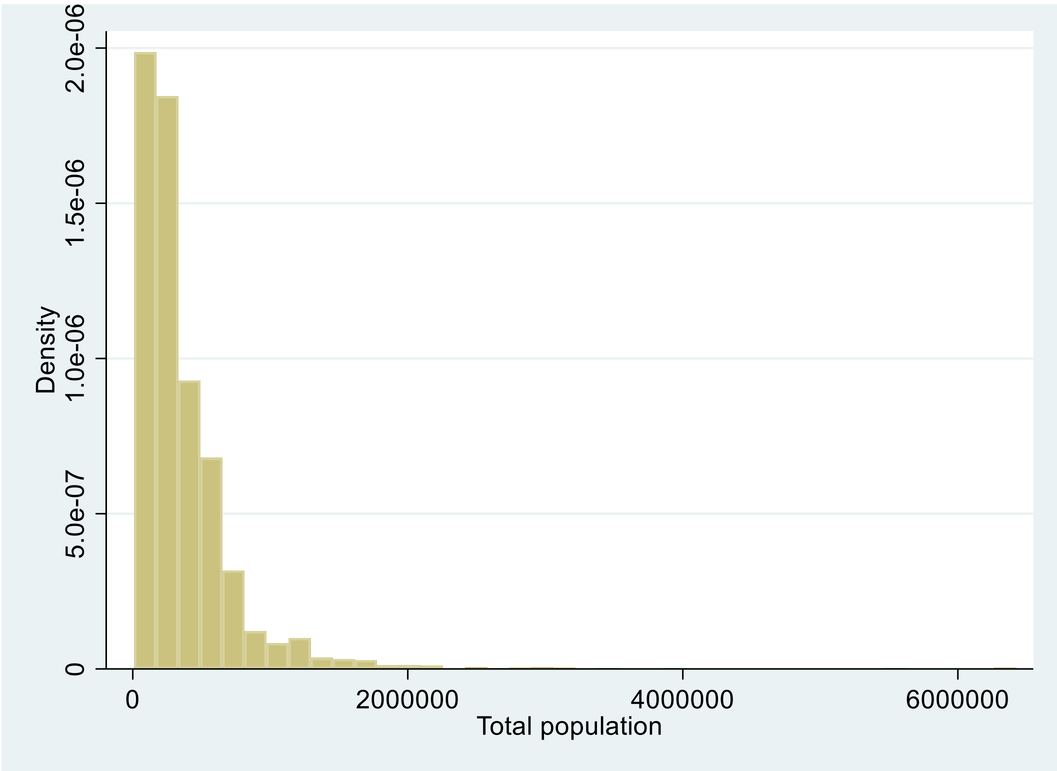




Density
0
5.0e-04
.001
.0015
0
5000
10000
15000
20000
Inhabitants per sqkm



Density
0
1
2
3
0
1
2
3
4
5
Employment to population ratio



Density
0
5.0e-07
1.0e-06
1.5e-06
2.0e-06
0
2000000
4000000
6000000
Total population