
Does increased trade openness enhance the impact of transport infrastructure investment on economic growth?

Marko Miljković

University of Belgrade, Faculty of Transport and Traffic Engineering, Serbia

e-mail: m.miljkovic@sf.bg.ac.rs

ORCID: [0000-0001-6232-6442](https://orcid.org/0000-0001-6232-6442)

Svetozar Tanasković

University of Belgrade, Faculty of Economics and Business, Serbia

e-mail: svetozar.tanaskovic@ekof.bg.ac.rs

ORCID: [0000-0002-2903-6520](https://orcid.org/0000-0002-2903-6520)

Jelica Petrović Vujačić

University of Belgrade, Faculty of Transport and Traffic Engineering, Serbia

e-mail: j.petrovic@sf.bg.ac.rs

ORCID: [0000-0003-1897-8990](https://orcid.org/0000-0003-1897-8990)

Ivan Vujačić

University of Belgrade, Faculty of Economics and Business, Serbia

e-mail: ivan.vujacic@ekof.bg.ac.rs

ORCID: [0000-0001-6025-5513](https://orcid.org/0000-0001-6025-5513)

© 2025 Marko Miljković, Svetozar Tanasković, Jelica Petrović Vujačić, Ivan Vujačić

This work is licensed under the Creative Commons Attribution-ShareAlike 4.0 International License.

To view a copy of this license, visit <http://creativecommons.org/licenses/by-sa/4.0/>

Quote as: Miljković, M., Tanasković, S., Petrović Vujačić, J., & Vujačić, I. (2025). Does increased trade openness enhance the impact of transport infrastructure investment on economic growth? *Argumenta Oeconomica*, 2(55), 218-232.

DOI: [10.15611/aoe.2025.2.14](https://doi.org/10.15611/aoe.2025.2.14)

JEL: H54, O47, R42

Abstract

Aim: This paper focuses on the impact of transport infrastructure investment on the economic growth of European countries, with a particular emphasis on analysing the effects of investment in both road and railway infrastructure in the first two decades of this century. The primary objective was to empirically test whether greater trade openness amplifies the positive effects of investment in transport infrastructure on economic growth.

Methodology: The panel data analysis approach was employed for its numerous advantages over time-series or cross-section analyses, encompassing a sample of 19 European countries from 2001 to 2021. Following the results of the applied econometric tests, models were estimated using generalised least squares (GLS) and ordinary least squares with panel-corrected standard errors (PCSE) methods.

Results: The results revealed the positive impact of transport infrastructure investment on economic growth, with a pronounced significance associated with rail infrastructure investment, especially in the most developed countries. Road infrastructure investment only exhibited a positive impact in transition countries. Crucially, the analysis determined that the positive effects of investing in transport infrastructure on economic growth intensified with increasing trade openness.

Implications and recommendations: The implications of the findings suggest that transport infrastructure investment alone is insufficient to drive economic growth. Other conditions must also be satisfied, particularly the economic integration of the country. Consequently, alongside transport infrastructure investment, it is essential to foster high levels of trade openness to ensure significant positive effects on the economy. Future research should further explore the significance of additional enabling conditions, such as a well-educated workforce and improved institutional environments, in facilitating and enhancing the positive effects of transport infrastructure investment.

Originality/value: Given that the most significant investment in developing high-quality transport infrastructure within the European Union took place in the two first decades of this century, this research offers valuable insights through its empirical analysis of this period, deepening the understanding of the relationship between transport infrastructure investment and economic growth in Europe. The study's value lies in identifying the particularly strong positive impact of investing in rail infrastructure in the most developed countries, alongside the positive influence of investing in road infrastructure, especially in transition countries where motorways comprise the largest share of investment projects. The originality of this research largely stems from its quantitative verification that increased trade openness enhances the positive effects of investing in transport infrastructure on economic growth.

Keywords: transport infrastructure, investment, economic growth, trade openness

1. Introduction

Investment in transport infrastructure and its economic effects have been the subject of scientific analysis for several decades. Following the pioneering research of Aschauer (1989), the macroeconomic approach has dominated the literature on this topic, the primary focus being the impact of transport infrastructure investment on productivity and economic growth. Most studies have confirmed the hypothesis of its positive impact on economic growth (e.g. Garcia et al., 2017; Calderon & Servén, 2004; European Commission, 2014; Broyer & Gareis, 2013). However, the intensity of this impact varied depending on the different units of analysis, the time periods considered and the types of transport infrastructure examined. More recently, some studies indicated insignificant effects (Cantos et al., 2005; Straub & Terada Hagiwara, 2010), while others even suggested a negative relationship between investment in certain types of transport infrastructure and economic growth in some countries (Sutherland et al., 2009).

Concerning the situation in Europe, the first trans-European transport network policy was launched at the end of the last century, while the most significant investment projects in developing high-quality transport infrastructure within the European Union occurred in the first decades of this century. The aim of this paper was to provide an empirical analysis of this period in order to contribute to a better understanding of the relationship between transport infrastructure investment and economic growth in Europe. The impact of investment in road and rail infrastructure was analysed separately to identify their possible distinct contributions to economic growth.

This paper also focuses on analysing whether the level of economic integration of a country can enhance the effects of transport infrastructure investment on economic growth. There are several reasons why this question is important. Some theoretical perspectives suggest that the positive economic impact of transport infrastructure investment depends on various other conditions, such as economic, investment, political and institutional factors (Banister & Berechman, 2001), hence a country's economic integration represents a necessary economic condition. Straub and Terada-Hagiwara (2010) emphasize in particular the importance of regional integration, highlighting that the positive effects of transport infrastructure investment on growth are evident in high-income countries that are strongly regionally economically integrated, whereas such effects are absent in less integrated countries.

Fedderke and Garlick (2008) stated that the impact of infrastructure on economic growth, beyond its role as a specific production factor and a complement to other production factors, a stimulus for the accumulation of production factors, and a driver of aggregate demand, can also be viewed through the lens of industrial policy. They argued that the development of infrastructure encourages private sector investment. Moreover, if a country or region experiences greater economic integration and trade openness, this impact will be even stronger. A larger available market attracts additional private sector investment, enabling higher profits not only by reducing costs through improved infrastructure but also by increasing income due to the expanded market (Crescenzi & Rodríguez-Pose, 2012). Therefore, the primary contribution of this paper was to empirically examine the role of trade openness – an indicator of a country's economic integration – in enabling and intensifying the positive effects of investing in transport infrastructure on the economic growth of European countries.

After reviewing the economic literature on the related subject, the section on methodology outlines the procedures and methods of panel data analysis. The author considered the empirical analysis of nineteen European countries over a period of twenty-one years, as well as the data, variables, and sample used. The results of both the econometric tests and the primary findings of the considered models are then presented. Finally, in the concluding section, the obtained results are discussed and compared with findings from other literature, leading to the conclusions.

2. Literature review

Approaches to studying the economic effects of transport infrastructure investment vary in terms of temporal and spatial coverage, choice of dependent variables, indicators of infrastructure development, and the methods of analysis employed, thus the literature review could be organized according to any of these criteria. However, since this empirical research focused on a sample of European countries, the literature findings are presented based on geographical principles, specifically by region, starting with Europe.

The existing research predominantly indicates a positive economic impact of transport infrastructure investment in European countries. Broyer and Gareis (2013) found that increased investment in transport infrastructure stimulated growth in production, employment, as well as private investment. The authors assessed the multiplier effect of these investment projects, estimating that each euro invested in infrastructure generates additional 14 euros in GDP, noting the positive impact on GDP growth was particularly pronounced during the recession and suggesting that investment in transport infrastructure should continue even during fiscal consolidation efforts in Europe following the global economic crisis. Similarly, Revoltella et al. (2016) identified the stronger effect of infrastructure on growth in regions of countries that suffered more during the recession, also suggesting that infrastructure investment can mitigate recessionary impacts.

Some studies stressed the importance of long-term effects on economic growth. The European Commission (2014) identified the positive impact of infrastructure on GDP per capita and long-term economic growth across 27 European countries from 1950 to 2012, noting the absence of mutual

causality between these two variables. Zhang and Cheng (2023) concluded that, in the case of the United Kingdom in the period from 1970 to 2017, transport infrastructure stock had a positive and significant effect on long-term economic growth, whereas large, expensive infrastructure projects harmed economic growth in the short run, thus emphasising the need for the implementation of a government stabilising policy.

When analysing the economic effects of infrastructure by type of transport, most attention was often given to road infrastructure, which is also the most developed. Stephan (2001) discovered a positive relationship between investment in road infrastructure and regional development levels in a sample of 21 French regions from 1978 to 1995, and 11 West German states from 1970 to 1995. Importantly, the study found that regional development levels did not influence the allocation of investment in road infrastructure among these regions. Similarly, Gaus and Link (2020) concluded that, in the case of 401 German counties, those endowed with and surrounded by more motorways tended to be significantly more productive than less connected regions. Ignatov (2024) utilised detailed data on the expansion of motorways in Europe from 1990 to 2020 and found that investment in transport infrastructure generated various economic benefits, including a reduction in income disparities between rich and poor regions.

In addition to findings regarding the positive effects, there were also indications of the negative effects of investment in transport infrastructure in some European countries. For instance, Lenz et al. (2018) concluded that investment in road infrastructure positively affected economic growth in Central and Eastern European countries, while such projects in rail infrastructure had negative effects. This disparity can be attributed to the fact that rail infrastructure had lagged behind for decades in these countries, as the majority was concentrated on the construction and modernisation of motorways.

Although Sutherland et al. (2009) identified a generally positive relationship between increasing road and, especially, rail infrastructure and economic growth in a sample of 24 OECD countries from 1960 to 2005, the situation varied across individual countries. For instance, negative impact caused by investment in road infrastructure was noted in France, Greece, the Netherlands and Spain, whilst Belgium, Portugal and Spain experienced negative effects brought on by investment in rail infrastructure, most likely due to excessive expenditure or inefficient use of the infrastructure. Additionally, a more pronounced impact on growth was observed in countries with lower levels of infrastructure development.

In the same vein, Butkus et al. (2023) analysed the impact of transport infrastructure investment on the economic growth of European Union member states from 2000 to 2019, and found a positive and statistically significant effect regarding the entire sample. However, they concluded that in countries with low levels of corruption control, transport infrastructure investment had a significant negative effect on growth, emphasising the importance of institutional development.

Purwanto et al. (2017) highlighted the enhanced competitiveness of firms as one of the key broader economic benefits of investing in transport infrastructure, while Teclean (2022) identified port and air transport infrastructure as the most relevant for economic competition within the EU, followed by road networks. Although railroad and inland waterways are viewed as less important competitiveness factors, they are seen as transport systems with high potential, particularly in light of the trends towards sustainable development and the EU's green initiatives.

In the case of America and Australia, some earlier studies relying primarily on data regarding the total level of public capital had a major impact in the literature. Aschauer (1989) found that non-military public capital, including roads, motorways, airports, public transportation infrastructure, energy infrastructure, and water and sewer systems, significantly impacted the total factor productivity of the US economy from 1949 to 1985, helping to explain the slowdown in productivity growth during the 1970s. In a later study, Aschauer (1990) stressed the importance of highways in increasing the marginal product of private capital, thereby encouraging private sector investment, production growth, and rising per capita income. Similarly, Kam (2001) analysed the Australian economy from 1930 to 1991 and concluded that the accumulation of public capital had positive short-term and long-term effects

on economic growth, whereas a recent study by Hooper et al. (2021) highlighted issues of income inequality, concluding that, based on an analysis of US states from 1976 to 2008, a reduction in spending on motorways could lead to an increase in inequality in a very short period of time.

Studies focusing on the Asian region, primarily on China, yielded important conclusions underlining the complexity of the relationship between transport infrastructure and economic growth. Yu et al. (2012) discovered that investment in infrastructure had no significant effect on economic growth in the western and central regions of China, primarily due to the low levels of technological advancement and the lack of an educated workforce, whilst a positive impact on growth was observed in the more developed eastern provinces. Zou et al. (2008) also concluded that insufficient transport infrastructure and investment were the main barriers to economic development in the western provinces, hence they recommended prioritising investment in road infrastructure over rail infrastructure, as road development not only promotes growth but also mitigates income inequality. In a more recent study, Shi et al. (2024) identified the significant positive impact of freight volume, encompassing road, waterway, and air cargo transport, on economic activity in 11 cities in China in the period from 2010 to 2020 – in contrast, the impact of passenger transport was relatively small. This finding suggests that increasing investment in freight transport infrastructure is a key strategy for enhancing economic development.

Mohmand et al. (2017) concluded, based on their analysis of Pakistan, that infrastructure investment alone cannot boost the economies of underdeveloped regions. The study emphasised that both physical infrastructure and social infrastructure investments were necessary to promote growth. Straub and Terada-Hagiwara (2010) studied the impact of transport infrastructure on economic growth in 102 developing countries from 1971 to 2006, and while the overall impact of road and railway infrastructure was found to be insignificant, interactions of variables denoting the development of infrastructure with a dummy variable indicating Asian countries revealed significant effects. The authors highlighted the importance of regional integration and the better institutional environment in Asian countries as potential explanations for this phenomenon, but did not empirically validate their claims. In contrast, this paper empirically investigated whether economic integration, measured by trade openness, enhances the positive effects of transport infrastructure investment on economic growth in Europe.

Research primarily focusing on African countries highlights the positive economic impact on long-term growth. Specifically, Vinceline et al. (2024) analysed data from 1980 to 2023, finding that investment in road and railway infrastructure significantly boosted productivity and long-term economic growth in the Republic of Congo. Nyasha and Odhiambo (2024) conducted a study on South Africa between 1992 and 2021 and also concluded that investment projects in transport infrastructure were associated with increased economic growth in the long term. Their findings indicated that investment in transport infrastructure primarily exerts a positive influence on economic growth through supply-side channels such as enhanced productive capacities, and suggested that the impact of demand-side channels, which operate on shorter time horizons, is relatively less significant.

3. Methodology

The model's dependent variable is the annual real GDP growth rate, expressed as a percentage change. According to Fedderke and Garlick (2008), when investment serves as an indicator of infrastructure, the growth rate should be the dependent variable. Conversely, when examining explanatory variables such as the level of infrastructure, the level of GDP becomes the dependent variable. Data on transport infrastructure investment were collected from the relevant national institutions through the OECD survey entitled "Investment Spending in Transport Infrastructure".

The OECD recognises the importance of enhancing international comparability of data, which should serve as the basis for decision-making on transport infrastructure spending (OECD/ITF, 2013), however data for many countries were incomplete, with some time periods or types of transport infrastructure

missing. The availability of data predominantly shaped the sample's scope, and to include as many observations as possible, a sample of the following nineteen European countries was selected: Belgium, Croatia, Czechia, Estonia, Finland, France, Greece, Hungary, Italy, Latvia, Lithuania, the Netherlands, Norway, Poland, Slovakia, Slovenia, Spain Sweden, and Switzerland (N=19). The observation period spanned 21 years, from 2001 to 2021, resulting in a total of 399 observations (T=21).

The explanatory macroeconomic control variables anticipated to influence GDP growth included, in addition to transport infrastructure investment, other investments the employment rate, level of education, trade openness, and foreign direct investment. Investment is widely recognised as one of the most fundamental determinants of economic growth by all theoretical growth models, and its robustness is confirmed by the results of empirical studies (Moral-Benito, 2012). Employment was considered a crucial factor in stimulating faster productivity growth, particularly in technology and science-intensive sectors (Olejnik & Olejnik, 2019), as well as in upper-middle income countries (Bacovic, 2021). Human capital, a key component of various theoretical growth models, is often measured using proxies related to education (cf. Trpkova & Tashevska, 2011). Consistent with this, Cuaresma et al. (2014) found a robust positive association between the level of education and economic growth across 255 European regions during the 1995-2005 period. Similarly, Próchniak (2011) emphasised that human capital, as measured by the education level of the labour force, was one of the most significant determinants of economic growth in Central and Eastern European countries from 1993 to 2009. Trade openness and foreign direct investment (FDI) inflows also had a significant influence on economic growth through various channels (Boldeanu & Constantinescu, 2015). More detailed data on these variables can be found in Table 1.

Table 1. Dependent and explanatory variables

Variable	Abbreviation	Description	Source
Dependent variable			
Real GDP growth rate	GDP	GDP in constant prices, percent change	IMF (2024)
Explanatory variables on transport infrastructure investment			
Transport infrastructure investment (road + rail)	TI	Investment spending in transport infrastructure, % of GDP	OECD (2024)
Road infrastructure investment	Rd	Investment spending in road infrastructure, % of GDP	OECD (2024)
Rail infrastructure investment	RI	Investment spending in rail infrastructure, % of GDP	OECD (2024)
Other explanatory control variables			
Other investment	I	Gross fixed capital formation of the entire economy minus investment spending in transport infrastructure, % of GDP	Eurostat (2024)
Employment rate	Em	Employment to working-age (15+) population ratio	World Bank (2024)
Level of education	Ed	The ratio of total enrolment in tertiary education, regardless of age, to the population of the age group that officially corresponds to that level of education	World Bank (2024)
Trade openness	TO	The sum of exports and imports of goods and services measured as a share of gross domestic product	World Bank (2024)
Foreign direct investment	FI	Foreign direct investment net inflows, % of GDP	World Bank (2024)

Source: authors' elaboration.

Descriptive summary statistics, including the number of observations, mean, standard deviation, minimum, and maximum values for all variables used, can be found in Table 2. Regarding transport infrastructure investment, substantial differences are evident within the sample, with this indicator ranging from 0.29% to 3.73% of GDP. Moreover, road infrastructure investment outpaced rail infrastructure investment during the covered period, which was marked by significant variations in the real GDP growth rate, including the impact of the global economic crisis.

Table 2. Descriptive summary statistics

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Real GDP growth rate (GDP)	399	2.13	3.77	-14.84	13.79
Transport infrastructure investment (TI)	399	1.04	0.47	0.29	3.73
Road infrastructure investment (Rd)	399	0.73	0.43	0.04	3.39
Rail infrastructure investment (RI)	399	0.31	0.18	0.01	0.98
Other investment (I)	399	21.68	3.80	9.46	35.68
Employment rate (Em)	399	53.61	7.20	37.40	71.90
Level of education (Ed)	399	70.44	17.00	30.82	150.20
Trade openness (TO)	399	105.35	38.64	45.42	189.80
Foreign direct investment (FI)	399	3.19	4.36	-13.91	37.29

Source: authors' calculations using STATA software.

The following two-way error component regression model represented by equation (1) was considered:

$$GDP_{it} = \beta_0 + \beta_1 TI_{it} + \beta_2 I_{it} + \beta_3 Em_{it} + \beta_4 Ed_{it} + \beta_5 TO_{it} + \beta_6 FI_{it} + \mu_i + \lambda_t + v_{it}. \quad (1)$$

The error term was composed of the following: μ_i which represents the unobservable time-invariant individual-specific effect, λ_t indicating the unobservable country-invariant time-specific effect, and v_{it} denoting the remaining stochastic disturbance term. The panel data analysis approach was chosen for its numerous advantages over time-series or cross-section analyses, including controlling for individual heterogeneity, providing more informative data, increasing variability, reducing collinearity among variables, increasing degrees of freedom, and enhancing efficiency (Baltagi, 2008).

Various estimation techniques have been employed in the literature on panel data sets to analyse the nexus between economic growth and transport infrastructure. These techniques typically depend on the characteristics of the dataset and the fulfilment of the econometric assumptions associated with the models used. They include the ordinary least squares method (Aschauer, 1989), fixed-effects estimators (Sutherland et al., 2009), the generalised least squares method (Wang, 2002), various instrumental variable approaches (Cantos et al., 2005), generalised method of moments estimators (Calderon & Servén, 2004), and Granger causality tests (European Commission, 2014; Yu et al., 2012).

The choice of a specific estimator in this research was based on the results of testing econometric assumptions, which ensured unbiased, efficient and consistent estimates of the regression parameters, following the procedures suggested by Baltagi (2008). This involved estimating both the fixed effects (FE) model, which assumed that individual-specific and time-specific effects were fixed parameters, and the random effects (RE) model, which assumes these effects were random parameters. Testing for the existence of individual and time effects in these models should either justify their inclusion or indicate a pooled model with constant regression parameters, suggesting that these effects were insignificant. If individual or time effects were present, the choice between FE and RE specifications was determined using the Hausman specification test, which assesses the correlation between regressors and individual or time effects. If this correlation exists, the RE specification yields biased and inconsistent estimates, making the FE specification preferable due to its unbiased and consistent estimates. Conversely, if there is no correlation, the RE specification provides unbiased and efficient estimates compared to those from the FE specification.

However, in the presence of cross-sectional dependence and heteroscedasticity, the FE estimator may become both inefficient and biased. In such cases, it is advisable to estimate the model using the generalised least squares method (GLS) or the ordinary least squares method with panel-corrected standard errors (PCSE), as recommended by Greene (2018), Beck and Katz (1995), and Reed and Webb (2010).

The second model is analogous to the first but differs in that it examines investment in road and rail infrastructure separately, rather than aggregating them into total investment in transport infrastructure. This approach allows for the identification of any distinct effects associated with each type of investment:

$$GDP_{it} = \beta_0 + \beta_1 Rd_{it} + \beta_2 Rl_{it} + \beta_3 I_{it} + \beta_4 Em_{it} + \beta_5 Ed_{it} + \beta_6 TO_{it} + \beta_7 FI_{it} + \mu_i + \lambda_t + v_{it}. \quad (2)$$

To examine whether transport infrastructure investment has varying effects on the economic growth of European countries based on their levels of economic integration, the third model was also be evaluated:

$$GDP_{it} = \beta_0 + \beta_1 TI_{it} + \beta_2 TI_{it}TO_{it} + \beta_3 I_{it} + \beta_4 Em_{it} + \beta_5 Ed_{it} + \beta_6 TO_{it} + \beta_7 FI_{it} + \mu_i + \lambda_t + v_{it}. \quad (3)$$

A positive estimated value for the parameter β_2 in the interaction between transport infrastructure investment and trade openness was expected, which would indicate that the impact of transport infrastructure investment on economic growth is more pronounced in countries with higher levels of trade openness.

4. Results

Regarding the results of the econometric tests presented in Table 3, it can be concluded that there were both individual-specific and time-specific effects in the model, yet the Hausman specification test rejected the random effects model estimator in favour of a fixed effects specification. Furthermore, the panel data showed evidence of heteroscedasticity, serial correlation, and cross-section dependence. Ignoring these econometric issues would result in inefficient estimates of the regression coefficients and biased standard errors. Therefore, the model was estimated using the GLS and PCSE methods. In light of the identified individual and time effects, these were incorporated directly into all equations through the inclusion of dummy variables.

Table 3. Results of econometric tests

Econometric tests	Null hypothesis	Test results
F-test of individual effects in fixed specification	No individual specific effects	F (18,355) = 3.16***
LM test of individual effects in random specification	No time specific effects	$\chi^2 (1) = 65.42***$
F-test of time effects in fixed specification	No individual specific effects	F (19,336) = 17.95***
LM test of time effects in random specification	No time specific effects	$\chi^2 (19) = 326.13***$
Robust Hausman specification test	Random effects specification	$\chi^2 (6) = 19.08***$
Wald test of heteroscedasticity in fixed specification	Homoscedasticity	$\chi^2 (19) = 433.93***$
Bhargava-Franzini-Narendranathan Durbin-Watson test of serial correlation in fixed specification	Serial independence	BFN = 1.297**
LM test of cross-sectional dependence in fixed specification, given that T > N	Cross-sectional independence	$\chi^2 (171) = 664.07***$

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Source: authors' calculations using STATA software.

Beck and Katz (1995) highlighted the advantages of using the PCSE method, noting that the GLS method tended to produce biased estimates of standard errors, despite being more efficient. However, a more recent study by Reed and Webb (2010) found that the efficiency of estimates obtained using the PCSE method in small samples, specifically those with N=10 and T=20, was approximately 40% lower than that of the GLS method, particularly in the presence of serial correlation, as in this study. Considering these findings, the models were estimated using both GLS and PCSE estimators.

The results of the Pesaran CIPS unit root test, a second-generation test that accounts for cross-sectional dependence (Pesaran, 2007), are presented in Table 4. The null hypothesis assumes that all series are non-stationary. It was found that all variables were stationary, except for rail infrastructure investment, level of education, and trade openness. The first differences of these non-stationary variables were found to be stationary; therefore, they were utilised in all the models.

Table 4. Results of the Pesaran CIPS unit root test

Variable	Specification without trend		Specification with trend	
	lags (0)	lags (1)	lags (0)	lags (1)
Real GDP growth rate (GDP)	-6.951***	-3.468***	-4.531***	-0.925
Transport infrastructure investment (TI)	-0.944	-2.478***	0.016	-1.248*
Road infrastructure investment (Rd)	-1.030	-2.599***	-0.741	-2.186**
Rail infrastructure investment (RI)	-0.459	-0.416	-0.643	-0.217
Rail infrastructure investment, first difference (RI_d1)	-11.153***	-5.884***	-8.785***	-3.523***
Other investment (I)	-1.744**	-2.239**	-2.240**	-2.507***
Employment rate (Em)	4.332	1.997	1.518	-2.254***
Level of education (Ed)	2.796	0.894	3.209	0.547
Level of education, first difference (Ed_d1)	-3.940***	-2.208***	-2.335***	-0.940
Trade openness (TO)	2.196	0.989	4.827	3.876
Trade openness, first difference (TO_d1)	-4.943***	-1.625**	-3.319***	-0.194
Foreign direct investment (FI)	-6.312***	-2.128**	-4.439***	0.914

Notes: The optimal lag length, calculated using the Akaike information criterion, ranges from 0 to 1 for all variables. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Source: authors' calculations using STATA software.

Table 5 presents the results of all the three defined models, utilising both the GLS and PCSE methods. In the context of model (1), transport infrastructure investment had a positive and significant effect on economic growth when estimated with the GLS method, however parameter β_1 associated with transport infrastructure investment was not significant when assessed using the PCSE method, indicating that this estimate was not robust to changes in the estimator.

Table 5. Impact of total transport infrastructure investment on economic growth, GLS and PCSE results

Explanatory variables	GLS			PCSE		
	Model (1)	Model (2)	Model (3)	Model (1)	Model (2)	Model (3)
Transport infrastructure investment variables						
Transport infrastructure investment (TI)	0.407*** (0.045)		-2.536*** (0.030)	0.346 (0.351)		-2.528*** (0.933)
Road infrastructure investment (Rd)		0.214*** (0.039)			0.187 (0.366)	
Rail infrastructure investment, first difference (RI_d1)		1.638*** (0.108)			1.520* (0.869)	
Interaction between transport infrastructure investment and trade openness (TI×TO)			0.029*** (0.001)			0.029*** (0.008)
Other macroeconomic control variables						
Other investment (I)	0.426*** (0.012)	0.429*** (0.012)	0.466*** (0.003)	0.419*** (0.092)	0.423*** (0.090)	0.469*** (0.088)
Employment rate (Em)	0.032*** (0.008)	0.035*** (0.009)	-0.010*** (0.002)	0.038 (0.063)	0.041 (0.061)	-0.011 (0.068)
Level of education, first difference (Ed_d1)	-0.002 (0.007)	0.007 (0.006)	0.018*** (0.002)	-0.004 (0.057)	0.008 (0.055)	0.018 (0.056)
Trade openness, first difference (TO_d1)	0.071*** (0.002)	0.068*** (0.003)	0.053*** (0.001)	0.070** (0.028)	0.066** (0.028)	0.054 (0.027)
Foreign direct investment (FI)	-0.015*** (0.001)	-0.015*** (0.001)	-0.016*** (0.001)	-0.015** (0.008)	-0.015* (0.008)	-0.016 (0.008)
Significance indicators						
Model significance	$\chi^2(43) = 5.9 \times 10^{6***}$	$\chi^2(43) = 5.9 \times 10^{6***}$	$\chi^2(44) = 1.1 \times 10^{6***}$	$\chi^2(43) = 2.5 \times 10^{4***}$	$\chi^2(44) = 2.3 \times 10^{4***}$	$\chi^2(44) = 2.1 \times 10^{4***}$
Determination coefficient				R ² =0.7589	R ² =0.7603	R ² =0.7674
Joint significance of the following variables: TI & TI×TO			$\chi^2(2) = 2.2 \times 10^{4***}$			$\chi^2(2) = 16.11***$

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Source: authors' calculations using STATA software.

In a similar way, equation (2) indicated the positive impact of investment in both road and rail infrastructure on economic growth, with significance at the 1% level when employing the GLS method. In contrast, when using the PCSE method, the impact of rail infrastructure investment on economic growth remained significant only at the 10% level, whilst the effect of road infrastructure investment was not significant.

Some studies also indicated that the impact of transport infrastructure investment was less significant. Del Bo and Florio (2008) conducted an empirical study involving 261 NUTS-2 regions of the European Union from 1995 to 2005, examining the impact of various types of transport infrastructure on economic growth, and found the positive impact of total infrastructure on GDP growth, with road and rail infrastructure having a significantly lesser effect than accessibility indicators such as potential multi-modal access and time to market, possibly reflecting the advanced state of infrastructure in Europe. The authors also identified the negative impact of investment projects in other roads, probably attributed to social factors associated with their construction.

In addition to the unfulfilled additional economic, investment, political, and institutional conditions emphasised by Banister and Berechman (2001), one possible reason for the insignificant impact of infrastructure investment on economic growth could be the existence of a non-linear relationship. Infrastructure investment can positively influence economic growth only up to a certain threshold, and beyond that point its impact becomes uncertain (Raihan, 2011). Crescenzi et al. (2015) pointed out that in developed countries, further investment in infrastructure brings limited effects on growth due to the diminishing marginal returns of capital. Moreover, poor investment decisions, particularly those driven by political motives rather than sound economic considerations, along with issues of corruption, can significantly undermine the effectiveness of transport infrastructure investments. Another potential explanation for the lack of impact is the spillover effect from one region to another, which can result in a lack of significant overall benefits (Forkenbrock & Foster, 1990).

The results of the joint significance test for transport infrastructure investment and its interaction with trade openness, defined in the model by equation (3), indicated significance at the 1% level, regardless of whether the GLS or PCSE method was applied. Furthermore, the interaction coefficient β_2 was positive, with a value of 0.029, suggesting that the impact of transport infrastructure investment on economic growth is greater in countries with higher levels of trade openness. Specifically, for each additional percentage point increase in trade openness, the effect of transport infrastructure investment on economic growth increased by an additional 0.029 percentage points.

Given the negative coefficient for β_1 associated with transport infrastructure investment, one can identify the threshold level of trade openness above which this investment positively influences economic growth. Based on the equation $-2.536 + 0.029 \times TO = 0$ for the GLS method and $-2.528 + 0.029 \times TO = 0$ for the PCSE method, the authors found nearly identical trade openness thresholds of 87.45% of GDP (GLS method) and 87.17% of GDP (PCSE method). Thus, the impact of transport infrastructure investment on economic growth becomes positive only when trade openness exceeds these threshold levels.

The robustness of the results was further assessed through a sample split. The sample was divided based on the observation units into two categories: developed countries (Belgium, Finland, France, Greece, Italy, the Netherlands, Norway, Spain, Sweden, and Switzerland) and countries that have undergone the economic transition process (Croatia, Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, and Slovenia). Additionally, the sample was segmented by time frame, specifically the periods from 2001 to 2010 and from 2011 to 2021. The results of this robustness check regarding the primary explanatory variables of this study are presented in Table 6.

Table 6. Impact of transport infrastructure investment on economic growth, robustness checks to sample splits

Explanatory variables	GLS			PCSE		
	Model (1)	Model (2)	Model (3)	Model (1)	Model (2)	Model (3)
Sample split: developed countries, 2001-2021						
Transport infrastructure investment (TI)	-0.129 (0.280)		-1.748*** (0.002)	-0.412 (0.601)		-2.337** (1.070)
Road infrastructure investment (Rd)		0.016 (0.341)			-0.409 (0.822)	
Rail infrastructure investment, first difference (RI_d1)		3.701*** (0.637)			3.743** (1.744)	
Interaction between transport infrastructure investment and trade openness (TI×TO)			0.022*** (0.007)			0.030** (0.014)
Joint significance of the following variables: TI & TI×TO			$\chi^2(2) = 10.81^{***}$			$\chi^2(2) = 5.01^*$
Trade openness threshold			79.45			77.90
Sample split: transition countries, 2001-2021						
Transport infrastructure investment (TI)	1.119*** (0.236)		-1.111 (0.979)	0.954*** (0.324)		-1.805 (1.419)
Road infrastructure investment (Rd)		0.971*** (0.273)			0.770** (0.371)	
Rail infrastructure investment, first difference (RI_d1)		0.825 (0.596)			0.924 (0.896)	
Interaction between transport infrastructure investment and trade openness (TI×TO)			0.020** (0.008)			0.024** (0.012)
Joint significance of the following variables: TI & TI×TO			$\chi^2(2) = 26.83^{***}$			$\chi^2(2) = 11.07^{***}$
Trade openness threshold			55.55			75.21
Sample split: all countries, 2001-2010						
Transport infrastructure investment (TI)	1.044*** (0.265)		0.215 (0.957)	0.816** (0.392)		-1.173 (1.142)
Road infrastructure investment (Rd)		0.760** (0.355)			0.531 (0.472)	
Rail infrastructure investment, first difference (RI_d1)		2.136*** (0.544)			0.984 (1.095)	
Interaction between transport infrastructure investment and trade openness (TI×TO)			0.006 (0.011)			0.021* (0.011)
Joint significance of the following variables: TI & TI×TO			$\chi^2(2) = 7.14^{**}$			$\chi^2(2) = 7.59^{**}$
Trade openness threshold			35.83			55.86
Sample split: all countries, 2011-2021						
Transport infrastructure investment (TI)	0.378** (0.153)		-3.097*** (0.712)	0.455 (0.428)		-2.458** (1.240)
Road infrastructure investment (Rd)		0.199 (0.297)			0.352 (0.594)	
Rail infrastructure investment, first difference (RI_d1)		1.188*** (0.352)			1.066* (0.655)	
Interaction between transport infrastructure investment and trade openness (TI×TO)			0.034*** (0.007)			0.027*** (0.009)
Joint significance of the following variables: TI & TI×TO			$\chi^2(2) = 28.45^{***}$			$\chi^2(2) = 14.57^{***}$
Trade openness threshold			91.09			91.04

Note: ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively.

Source: authors' calculations using STATA software.

In developed countries, only investment projects in rail infrastructure demonstrated a positive impact. Conversely, in transition countries, only investment in road infrastructure showed a positive impact; these findings were in line with Lenz et al. (2018). Analysing the data by decade revealed a significantly larger impact in the first decade of this century, consistent with the principle of diminishing marginal returns to infrastructure capital. Finally, robustness checks confirmed the necessity of a certain degree of trade openness to achieve a positive impact of transport infrastructure investment on economic growth. This finding holds across all the segments of the original sample, whether divided by country or time period. Specifically, each subsample confirmed that greater trade openness is associated with a stronger impact of transport infrastructure investment on economic growth. Furthermore, most subsamples supported the existence of a minimum threshold of trade openness required for these positive effects to materialise at all. While this threshold did not consistently remain around 87% as observed in the entire original sample, it varied between approximately 36% and 91% of GDP.

This finding, arising from the estimation of the equation (3), empirically validates the assumption that for transport infrastructure investment to positively impact economic growth, certain additional conditions must be met, specifically the economic integration of a country and a minimum level of trade openness.

5. Discussion and conclusions

Numerous theoretical and quantitative studies have confirmed the positive economic effects of transport infrastructure investment. These effects include enhanced economic growth and development, improvements in total factor productivity, regional convergence, reductions in income inequality, increased employment, heightened private investment and competitiveness, and mitigation of the adverse effects of recession.

Conversely, some findings indicated the lack of positive effects from transport infrastructure investment on economic growth. This absence was often attributed to low levels of technological progress, a poorly educated labour force, an underdeveloped social infrastructure, an unfavourable institutional environment, and insufficient economic integration.

In the empirical analysis conducted in this study, the positive impact of transport infrastructure investment on economic growth was identified in a sample of 19 European countries from 2001 to 2021. Notably, investment in railway infrastructure demonstrated a particularly robust positive impact, resilient to variations in estimation methods. Furthermore, rail infrastructure investment had the largest impact on growth in the most developed European countries within the examined sample. This finding suggests that the policy of trans-European transport networks, which allocates the majority of funding for infrastructure within the nine Trans-European Transport Network (TEN-T) corridors of the core network to rail infrastructure, could be strategically beneficial for enhancing the economic growth of European nations.

Yet, while the impact of road infrastructure investments on economic growth was positive, such findings lack robustness across different assessment methods. Although multiple empirical literature pointed to the positive impact of investment in motorways on economic growth, investments in other roads in developed countries often showed insignificant or even negative effects. Given that motorway networks are generally well developed along key European corridors, one potential explanation for this lack of robustness was the high proportion of investment projects allocated to other roads within the broader category of road infrastructure, coupled with the diminishing marginal returns of infrastructure capital. Nevertheless, the results also indicated the positive impact of investing in road infrastructure specifically in transition countries which have the largest share of investment projects in motorways, which greatly contributed to their economic growth.

Addressing the primary research question, the analysis confirmed that investing in transport infrastructure has a more pronounced effect in economically integrated, or trade-open, economies.

This finding empirically supports previous assertions by Straub and Terada Hagiwara (2010) regarding the crucial role of country integration, as well as those by Banister and Berechman (2001) concerning the importance of economic conditions in facilitating the positive effects of transport infrastructure investment on economic growth. The results suggest that the threshold level of trade openness, above which positive effects of transport infrastructure investment on economic growth can be expected, is approximately 87% of GDP.

However, the value of this threshold varies depending on the sample division – in particular, a lower threshold was observed in transition countries compared to developed countries, and also in the first decade of this century compared to the second one. These variations may be related to the existing state and level of infrastructure development. More developed infrastructure may require additional conditions, such as greater economic integration, to yield positive impacts on economic growth. Regardless of the specific threshold value for trade openness, the conclusion remains consistent across all samples and subsamples: greater trade openness enhances the positive impact of investments in transport infrastructure on the economy.

The policy implications of these findings are significant, and suggest that the mere construction of infrastructure does not automatically lead to substantial economic growth. Therefore, governments should prioritise economic integration as it facilitates access to larger markets and fosters competition and private sector investment, ultimately driving higher economic growth. Furthermore, investing in transport infrastructure while promoting trade openness can enhance a country's geopolitical influence by positioning it as a key node in global supply chains.

Finally, it is important to note one potential limitation related to endogeneity. Namely, there is a certain possibility of endogeneity of explanatory variables in the sample in terms of their correlation with the error term that can be the result of a simultaneous relationship between the dependent and independent variables or other measurement errors or omission of variables, in which case the estimates obtained by the GLS and PCSE method would be efficient but biased. Nevertheless, an extensive check of the robustness of the results in relation to the estimation methods, as well as the division of the sample by observation units and by time periods, provides significant confidence in the reliability and consistency of these findings, although endogeneity was not explicitly tested.

In light of the conclusion of this paper, future research should further explore the significance of additional enabling conditions, such as a well-educated workforce and improved institutional environments, in facilitating and enhancing the positive effects of transport infrastructure investments.

References

- Aschauer, D. A. (1989). Is public expenditures productive? *Journal of Monetary Economics*, 23(2), 177-200. [https://doi.org/10.1016/0304-3932\(89\)90047-0](https://doi.org/10.1016/0304-3932(89)90047-0)
- Aschauer, D. A. (1990). Highway Capacity and Economic Growth. *Economic Perspectives*, 14(Sep), 14-24.
- Bacovic, M. (2021). Total factor productivity growth in upper middle income Balkan countries from 2000-2017, total economy and sectoral approach: The growth accounting method. *Argumenta Oeconomica*, 46(1), 79-97.
- Baltagi, B. (2008). *Econometric Analysis of Panel Data*. John Wiley & Sons Ltd.
- Banister, D., & Berechman, Y. (2001). Transport investment and the promotion of economic growth. *Journal of Transport Geography*, 9(3), 209-218. [https://doi.org/10.1016/S0966-6923\(01\)00013-8](https://doi.org/10.1016/S0966-6923(01)00013-8)
- Beck, N., & Katz, J. (1995). What to do (and not to do) with time-series cross-section data. *American Political Science Review*, 89(3), 634-647.
- Boldeanu, F. T., & Constantinescu, L. (2015). The main determinants affecting economic growth. *Bulletin of the Transilvania University of Braşov, Series V: Economic Sciences*, 57(2), 329-338.
- Broyer, S., & Gareis, J. (2013). How large is the infrastructure multiplier in the euro area? *Flash Economics by Natixis Research*, No. 227.
- Butkus, M., Mačiulytė-Šniukienė, A., & Matuzevičiūtė, K. (2023). Transport infrastructure investments as a factor of economic growth of European Union countries. *TalTech Journal of European Studies*, 13(1), 150-176. <https://doi.org/10.2478/bjes-2023-0008>

- Calderon, C., & Servén, L. (2004). The effects of infrastructure development on growth and income distribution. *Working Papers Central Bank of Chile* 270, Central Bank of Chile.
- Cantos, P., Gumbau-Albert, M., & Maudos, J. (2005). Transport infrastructure and regional growth: Evidence of the Spanish case. *MPRA Paper* 15261, University Library of Munich, Germany.
- Crescenzi, R., & Rodríguez-Pose A. (2012). Infrastructure and regional growth in the European Union. *Papers in Regional Science*, 91(3), 487-513. <https://doi.org/10.1111/j.1435-5957.2012.00439.x>
- Crescenzi, R., Di Cataldo, M., & Rodríguez-Pose, A. (2015). Government quality and the economic returns of transport infrastructure investment in European regions. *Working Papers Collection A: Public Economics, Governance and Decentralization* 1508, University of Vigo, GEN – Governance and Economics Research Network.
- Cuaresma, J. C., Doppelhofer, G., & Feldkircher, M. (2014). The determinants of economic growth in European regions. *Regional Studies*, 48(1), 44-67. <https://doi.org/10.1080/00343404.2012.678824>
- Del Bo, C., & Florio, M. (2008). Infrastructure and growth in the European Union: an empirical analysis at the regional level in a spatial framework. *Departmental Working Papers* 2008-37, Department of Economics, Management and Quantitative Methods at Università degli Studi di Milano.
- European Commission. (2014). Infrastructure in the EU: Development and impact on growth. *European Economy Occasional Papers* 203.
- Eurostat. (2024). Dataset on *Gross fixed capital formation by AN_F6 asset type*. Retrieved October 1st, 2024 from https://doi.org/10.2908/NAMA_10_AN6
- Fedderke, J., & Garlick, R. (2008). Infrastructure development and economic growth in South Africa: A review of the accumulated evidence. *Policy Paper Number* 12, University of Cape Town.
- Forkenbrock, D. J., & Foster, N. S. J. (1990). Economic benefits of a corridor highway investment. *Transportation research. Part A: General*, 24(4), 303-312. [https://doi.org/10.1016/0191-2607\(90\)90007-S](https://doi.org/10.1016/0191-2607(90)90007-S)
- García, V. A., Meseguer, J. A., Ortiz, L. P., & Tuesta, D. (2017). Infrastructure & economic growth from a meta-analysis approach: Do all roads lead to Rome? *BBVA Research Working Paper* No 17/07, BBVA Bank, Economic Research Department.
- Gaus, D., & Link, H. (2020). Economic effects of transportation infrastructure quantity and quality: A study of German counties. *Discussion Papers of DIW Berlin* 1848, DIW Berlin, German Institute for Economic Research.
- Greene, W. H. (2018). *Econometric Analysis*. Pearson.
- Hooper, E., Peters, S., & Pintus, P. A. (2021). The impact of infrastructure investments on income inequality: Evidence from US states. *Economics of Transition and Institutional Change*, 29(2), 227-256.
- Ignatov, A. (2024). European highway networks, transportation costs, and regional income. *Regional Science and Urban Economics*, 104 (January 2024) Article 103969. <https://doi.org/10.1016/j.regsciurbeco.2023.103969>
- IMF. (2024). *World Economic Outlook Database, April 2024 Edition*. Retrieved October 1st, 2024 from <https://www.imf.org/en/Publications/WEO/weo-database/2024/April/>
- Kam, T. C. Y. (2001). Public infrastructure spillovers and growth: Theory and time series evidence from Australia. *Department of Economics Working Paper Series* 811, The University of Melbourne.
- Lenz, N. V., Skender, H. P., & Mirković, P. A. (2018). The impact of transport infrastructure on economic growth: Evidence from CEE. *EFRI Exclusive Working Papers* 2018-10, Faculty of Economics and Business, University of Rijeka.
- Mohmand, T. J., Wang, A., & Saeed, A. (2017). The impact of transportation infrastructure on economic growth: Empirical evidence from Pakistan. *Transportation Letters*, 9(2), 63-69. <https://doi.org/10.1080/19427867.2016.1165463>
- Moral-Benito, E. (2012). Determinants of economic growth: A Bayesian panel data approach. *The Review of Economics and Statistics*, 94(2), 566-579, MIT Press. https://doi.org/10.1162/REST_a_00154
- Nyasha, S., & Odhiambo, N. M. (2024). Does transport infrastructure spur economic growth in South Africa? An empirical investigation. *Facta Universitatis, Series: Economics and Organization*, 21(2), 73-85. <https://doi.org/10.22190/FUEO240405005N>
- OECD. (2024). *ITF transport statistics – transport infrastructure investment and maintenance*. Retrieved October 1st, 2024 from <https://doi.org/10.1787/trsprt-data-en>
- OECD/ITF. (2013). *Understanding the value of transport infrastructure – guidelines for macro-level measurement of spending and assets*. OECD International Transport Forum.
- Olejnik, A., & Olejnik, J. (2019). Increasing returns to scale, productivity and economic growth – a spatial analysis of the contemporary EU Economy. *Argumenta Oeconomica*, 42(1), 273-293.
- Pesaran, M. H. (2007). A simple panel unit root test in the presence of cross-section dependence. *Journal of Applied Econometrics*, 22(2), 265-312. <https://doi.org/10.1002/jae.951>
- Próchniak, M. (2011). Determinants of economic growth in Central and Eastern Europe: the global crisis perspective. *Post-Communist Economies*, 23(4), 449-468. <https://doi.org/10.1080/14631377.2011.622566>
- Purwanto, A. J., Heyndrickx, C., Kiel, J., Betancor, O., Socorro, M. P., Hernandez, A., Eugenio-Martin, J. L., Pawlowska, B., Borkowski, P., & Fiedler, R. (2017). Impact of transport infrastructure on international competitiveness of Europe. *Transportation Research Procedia*, 25, 2877-2888. <https://doi.org/10.1016/j.trpro.2017.05.273>

- Raihan, S. (2011). Infrastructure and growth and poverty in Bangladesh. MPRA Paper 37882, University Library of Munich.
- Reed, W. R., & Webb, R. (2010). The PCSE estimator is good – just not as good as you think. *Journal of Time-Series Econometrics*, 2(1), 1-26. <https://doi.org/10.2202/1941-1928.1032>
- Revoltella, D., Brutscher, P. B., Tsiotras, A., & Weiss, C. (2016). Infrastructure investment in Europe and international competitiveness. *EIB Working Papers* 2016/01, European Investment Bank.
- Shi, J., Bai, T., Zhao, Z., & Tan, H. (2024). Driving economic growth through transportation infrastructure: An in-depth spatial econometric analysis. *Sustainability*, 16(10), 4283. <https://doi.org/10.3390/su16104283>
- Stephan, A. (2001). Regional infrastructure policy and its impact on productivity: a comparison of Germany and France. CIG Working Papers FS IV 00-02, Wissenschaftszentrum Berlin (WZB), Research Unit: Competition and Innovation (CIG).
- Straub, S., & Terada-Hagiwara, A. (2010). Infrastructure and growth in developing Asia. *Asian Development Bank Economics Working Paper Series* No. 231.
- Sutherland, D., Araujo, S., Égert, B., & Koźluk, T. (2009). Infrastructure investment: Links to growth and the role of public policies. *OECD Economics Department Working Papers* 686, OECD Publishing.
- Teclean, C. (2022). The impact of the quality of transport networks on economic competitiveness in the European Union. *CES Working Papers*, 14(2), 114-132. Centre for European Studies, Alexandru Ioan Cuza University.
- Trpkova, M., & Tashevska, B. (2011). Determinants of economic growth in South-East Europe: A panel data approach. *Perspectives of Innovation in Economics and Business*, 7(1), 12-15.
- Vinceline, P. C., Guo, S. Q., & Keeven, N. R. M. C. (2024). Analysis of the impact of transport infrastructure on economic growth in the Republic of Congo. *American Journal of Industrial and Business Management*, 14(10), 1288-1302. <https://doi.org/10.4236/ajibm.2024.1410065>
- Wang, E. C. (2002). Public infrastructure and economic growth: A new approach applied to East Asian economies. *Journal of Policy Modeling*, 24(5), 411-435. [https://doi.org/10.1016/S0161-8938\(02\)00123-0](https://doi.org/10.1016/S0161-8938(02)00123-0)
- World Bank. (2024). *World Bank Open Data*. Retrieved October 1st, 2024, from <https://data.worldbank.org/>
- Yu, N., De Jong, M., Storm, S., & Mi, J. (2012). Transport infrastructure, spatial clusters and regional economic growth in China. *Transport Reviews*, 32(1), 3-28. <https://doi.org/10.1080/01441647.2011.603104>
- Zhang, Y., & Cheng, L. (2023). The role of transport infrastructure in economic growth: Empirical evidence in the UK. *Transport policy*, 133, 223-233. <https://doi.org/10.1016/j.tranpol.2023.01.017>
- Zou, W., Zhang, F., Zhuang, Z., & Song, H. (2008). Transport infrastructure, growth and poverty alleviation: Empirical analysis of China. *Annals of Economics and Finance*, 9(2), 345-371.

Received: November 2024, revised: March 2025