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Transport Infrastructure Investments as a Factor of Economic Growth of European Union Countries

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Abstract: Territorial cohesion and improved accessibility are among the main objectives of the European Union (EU) Cohesion policy. Although there is a wealth of literature on the impact of investment in transport infrastructure on overall accessibility levels, only a few studies have tried to evaluate the possible link between transport infrastructure investment (TII) and economic growth in the EU. Our research aims to evaluate the impact of TII on economic growth in the EU. The methodology is based on non-linear neoclassical specification, which includes a multiplicative term to evaluate if the absence of corruption mediates the effect of TII on growth. Our unbalanced panel data covers 27 EU countries (Cyprus is excluded due to missing data and the United Kingdom

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is a part of the sample) from 2000 through 2019. Our research confirms a positive and statistically significant impact of TII on economic growth but with a diminishing return. Estimating the absence of corruption as a possible moderator of the effect that TII has on growth shows that control of corruption plays a significant role in the TII growth nexus. We find that in countries with a low level of control of corruption, TII has a statistically significant negative effect on growth.

Keywords: *control of corruption, diminishing marginal effects, economic growth, transport infrastructure, transport infrastructure investment*

1. Introduction

Transport infrastructure development plays a vital role in stimulating economic activity and is one of the main factors of societies' social well-being (Wang *et al*., 2020; Beifert, Prause & Shcherbanin, 2020; Kubera, 2020; Taylor, 2020). Therefore, countries allocate yearly large amounts of money to build new and improve ageing infrastructure. According to International Transport Forum (2013), it is critical to evaluate the infrastructure investment outputs so that policy makers can prioritize the allocation of investments.

In the last decade, the effects of infrastructure development have received considerable attention in scientific research. However, most studies cover China provinces (Liu & Hu, 2011; Hong, Chu & Wang, 2011; Wang *et al*., 2020) and evaluate relationships between physical infrastructure indicators or indexes and economic growth. Yu *et al*. (2012) estimated transport investment growth outcomes at the national level. What is the situation in the EU? Some studies cover EU countries (Crescenzi & Rodríguez-Pose, 2012; Lenz, Skender & Mirković, 2018) finding significant and positive impact on economic growth. The contradictory results were revealed by Luz *et al*. (2016) in the case of ten countries (including four EU countries), who did not find significant relationships between the transport infrastructure index and GDP. Also there are only few studies (Haque & Kneller, 2015; Crescenzi *et al*., 2016; Fazekas & Tóth, 2018; Kyriacou, Muinello-Gallo & Roca-Sagalés, 2019; Cigu *et al*., 2019) including different indicators for government quality as a moderator for TII impact on economic growth. Unfortunately, there

is a lack of research on the non-linear effects of transport infrastructure investments on economic growth in EU Member States (MS). To fill the identified research gaps, the study aims to evaluate the linear and non-linear effects of transport infrastructure investments on growth, taking into consideration possible mediating effects of corruption.

The article contributes to the previous research by estimating and justifying the existence of the non-linear effects of transport infrastructure investments on economic growth and highlighting the importance of corruption for the return on investment. This is very important in shaping the policy of allocation of funds from the EU and national budgets.

The remaining article is organized as follows: Section 2 discusses transmission channels of transport infrastructure investments to economic growth and the role of corruption; Section 3 presents research methodology and data; Section 4 provides the estimation results and discussion. The last section concludes the article.

2. Theoretical framework

The importance of modern transport infrastructure for economic growth and the population's well-being is unquestionable. Transport infrastructure (TI) is one of the parts of critical public infrastructure. In scientific literature, its effect is usually based on the public investment (PI) theory. At the macro level, PI increases aggregate demand, positively influences national incomes, raises nationwide savings, crowds private investment in other sectors, and promotes market integration (Anderson, de Renzio & Levy, 2006). At the micro level, quality and quantity and price effects occur. According to Anderson, de Renzio and Levy (2006), PI increases the quality and amount of public and private goods and services. Moreover, PI changes the prices of goods and services in the various markets, influencing economic growth.

Linking the PI theory specifically to TII, it should be noted that TI development can facilitate economic growth through different channels. According to Ejiogu, Madonsela and Adetunla (2020), TI influences industrial development as social capital and has a spill-over effect on factors redistribution and manufacturing efficiency. It is related to the accumulation of regional population, industry attraction, and economic growth. Meersman and Nazemzadeh (2017) and Cigu *et al*. (2019) distinguish between direct

and indirect channels through which TI can influence economic growth. The direct effect is manifested through the transport sector's contribution to GDP by providing easier access to inputs and reducing the cost of intermediate purchases. Moreover, development of TI increases government expenditure and the amount of fixed capital that directly raises GDP.

According to Meersman and Nazemzadeh (2017), indirect effects occur through positive impact on other sectors by providing cheaper, faster, more flexible and reliable transport services. This has led to higher productivity in manufacturing and other sectors. Advanced TI can encourage business development, grant more straightforward access to global suppliers and international markets, raise the effectiveness of the worldwide production process and reduce the prices of products by increasing accessibility and reducing transport costs. Those effects have a long-term nature. The effects of TI investments on economic growth were presented by Chen *et al*. (2021). The authors distinguish between three main channels: multiplier, cost-saving, and broader economic impact, related to increased accessibility of production factors. TI investments lead to transport sector development and promote multiplier effects on other sectors that stimulate productivity and economic growth. TI investment due to improved transport services ensures lower cost, time saving, and more reliability, raising total factor productivity.

Increased accessibility to production factors improves conditions for market expansion, specialization, and scale economy due reduction of trade barriers. Increased mobility of production factors led to innovation and knowledge diffusion and improved labor supply. Moreover, TI investments create jobs, raise employment in construction sectors and stimulate economic growth (Pradhan, Arvin & Nair, 2021). This effect is temporary, but as Rietveld and Bruinsma (1998) mentioned, governments use this tool to solve employment problems.

It is also essential to mention that the effect of TI development on economic growth differs in rural and urban areas (Ejiogu, Madonsela & Adetunla, 2020). Although the TI is less developed in rural areas, more significant economic benefits from TI investments occur in urban areas (Meersman & Nazemzadeh, 2017). Nevertheless, it is important that TI investments are directed to regions with the worst infrastructure. In this case, the equality of TI would be promoted. As Banerjee, Duflo & Qian (2020) and Chen *et al*. (2021) mentioned, TI inequality leads to negative consequences such as inefficient allocation of resources, knowledge spill-over interruption, and market vulnerability.

The efficiency of investment allocation could depend on the institutional quality (Butkus *et al*., 2020). The distribution of funds for TI projects is mainly influenced by corruption. For personal gains, corrupted governments tend to direct investment to large-scale projects, although this may reduce the efficiency of investments. Moreover, corruption leads to the crowding-out effect of private infrastructure investments, replacing them with public investments, that is, wasted investments (Zheng & Xiao, 2020). Since corruption increases the volume of investments, diminishing return on investment may occur.

Once investments reach a threshold level, they may not generate economic benefits or even lead to adverse effects. Therefore, in evaluating the impact of TI on economic growth, it is essential to assess not only the linear but also the non-linear effects in the light of moderating influence of corruption.

Kyriacou, Muinello-Gallo and Roca-Sagalés (2019) assessed transport investment efficiency using Data Envelopment Analysis of a sample of 34 countries (including 24 EU countries). They found that efficiency in different countries varies and depends on government quality. The authors focus on four dimensions of government quality: control of corruption, the rule of law, regulatory quality, and government effectiveness. These results show that it is appropriate to include government quality indicators, primarily the level of corruption, in transport investments output studies. Chen *et al*. (2022) assessed the effect of corruption on transport infrastructure in the United States of America and concluded that "prevention of corruption is crucial to improving infrastructure." A study by Fazekas and Tóth (2018) in Europe revealed that corrupt institutions channel transport infrastructure investment to high-value projects while ignoring low-value projects and reduce the efficiency of the investments due to price inflation by 30–35%. The negative impact of corruption on the efficiency of public investment was empirically substantiated also by Haque and Kneller (2015) in the case of 66 countries. The authors conclude that corruption increases public investment and reduces private investment, leading to lower investment efficiency. Non-linear U-shaped effects may occur if the flow of investment is too high.

When analyzing the previous research of TI on economic growth in EU, we find ambiguous results. Crescenzi and Rodríguez-Pose (2012) evaluated the impact of physical transport infrastructure (motorways) on GDP per capita in EU-15 at the regional level and found a significant positive but weak relationship that depends on regional conditions. They concluded that infrastructure endowment is a relatively poor predictor of economic growth.

Lenz, Skender and Mirković (2018) also evaluated the impact of physical infrastructure on the economic growth of Central and Eastern EU Member States. They found that the development of road networks has a significant positive impact, and the development of railway infrastructure has a negative impact. Contradictory results were revealed by Luz *et al*. (2016) in the case of ten countries (including four EU countries) and Cigu *et al.* (2019) in the case of EU-28 countries. They used indexes of transport infrastructure (ITI) proxy infrastructure. The evaluations by Luz *et al*. (2016) did not find significant relationships between the transport infrastructure index and GDP. In contrast, the evaluations of Cigu *et al.* (2019) identified the positive and significant impact of ITI on GDP per capita even after controlling institutional and other factors. The contradictions in the results may have been caused due to the different compositions of the ITI and the various methods used in the studies. However, this does not clarify the impact of infrastructure investment on the EU MS' economy.

3. Model and data

Thw analysis of the TII effect on growth is grounded on the neoclassical model, which is widely used in the conventional literature (Farhadi, 2015; Meersman & Nazemzadeh, 2017; Lenz, Skender & Mirković, 2018; Cigu *et al*., 2019; Elburz & Cubukcu, 2021; Muvawala, Sebukeera & Ssebulime, 2021):

$$\frac{1}{T-1} ln\left(\frac{Y_{i,t+T}}{Y_{i,t}}\right) = \alpha + \beta ln(Y_{i,t}) + c_1 cc_{i,t} + c_2 \Delta ln(pop_{i,t}) + c_3 ln(dens_{i,t}) + c_4 ln(urb_{i,t}) + c_5 \Delta ln(lf_{i,t}) + c_6 gcf_{i,t} + c_7 gcf_{i,t}^2 + c_8 ln(opn_{i,t}) + c_9 fdi_{i,t} + c_{10} ln(gov_{i,t}) + c_{11} ln(r\&d_{i,t}) + c_{12} \Delta ln(cpi_{i,t}) + c_{13} ln(hc_{i,t}) + \theta_t + \mu_i + \varepsilon_{i,t}, \quad \{1\}$$

where i and t are the subscript for the country and the year, respectively. $\frac{1}{T-1} ln\left(\frac{Y_{i,t+T}}{Y_{i,t}}\right)$ is the average year-to-year growth rate of the per capita GDP (Y) from year t to T. To control other growth factors, on the right-hand side of the specification, we include: income level at the initial period t, control of corruption (as a proxy for the absence of corruption), growth and density of population, level of urbanization level, labor force growth, private sector's capital investment and its squared term, openness for trade, foreign direct investment, size of the government, research and development, inflation

and human capital. The selection of factors is based on a literature review. There is no common set of control variables across studies. However, they often include labor force growth, research and devlopment, a measure representing human capital, size of the government sector, trade openness, foreign direct investment, and a measure of institutional quality (Crescenzi *et al*., 2016; Meersman & Nazemzadeh, 2017; Lenz, Skender & Mirković, 2018; Kyriacou, Muinello-Gallo & Roca-Sagalés, 2019; Cigu *et al*., 2019; Apurv & Uzma, 2020; Wang *et al*., 2020). All variables and their calculations are presented in Table 1. Term θ_t represents time effects which are modelled using time dummies. μ_i represents time-invariant country-specific effects which are controlled by estimating Eq. 1 using a within estimator. $\varepsilon_{i,t}$ is the idiosyncratic error term. β and $c_{(.)}$ are parameters to be estimated.

We add the transport infrastructure investments (*TII*) as a common growth factor to our Eq. 1:

$$\frac{1}{T-1} ln\left(\frac{Y_{i,t+T}}{Y_{i,t}}\right) = \alpha + \beta ln\left(Y_{i,t}\right) + \gamma_1 ln\left(TII_{i,t}\right) + c_1 cc_{i,t} + \cdots + \theta_t + \mu_i + \varepsilon_{i,t}, \quad \{2\}$$

We hypothesize that the absence of corruption affects the impact of transport infrastructure investment on growth. To test that, the following specification is relevant:

$$\frac{1}{T-1} ln\left(\frac{Y_{i,t+T}}{Y_{i,t}}\right) = \alpha + \beta ln\left(Y_{i,t}\right) + \gamma_1 ln\left(TII_{i,t}\right) + \varphi_1 ln\left(TII_{i,t}\right) \times cc_{i,t} + c_1 cc_{i,t} + \cdots + \theta_t + \mu_i + \varepsilon_{i,t}, \quad \{3\}$$

Where the product of *TII* and *cc* allows examining how the absence of corruption affects growth outcomes of transport infrastructure investment. Rearranging Eq. 3, we can demonstrate that *TII*×*cc*, allows modelling the conditional relationship between *TII* and growth, which depends on the absence of corruption:

$$\frac{1}{T-1} ln\left(\frac{Y_{i,t+T}}{Y_{i,t}}\right) = \alpha + \beta ln\left(Y_{i,t}\right) + \left[\gamma_1 + \varphi_1 \cdot cc_{i,t}\right] \times ln\left(TII_{i,t}\right) + c_1 cc_{i,t} + \cdots + \theta_t + \mu_i + \varepsilon_{i,t}, \{4\}$$

where $\gamma_1 + \varphi \cdot cc$ is the composite slope of growth on transport infrastructure investment.

Introducing the multiplicative term, the standard error associated with the slope coefficient also becomes conditional. It means that a certain level of the absence of corruption is needed for the significant effect of the TII on growth to appear. Here we apply formulae developed by Brambor, Clark and Golder (2006) to calculate conditional standard errors.

According to the assumptions of neoclassical growth theory, *TII*, like other types of investments, can be subject to diminishing marginal effects. We will test that assumption, that is, the possible non-linear inverted U-shaped form of the relationship between *TII* and growth, by adding the squared term of *TII* in our specification:

$$\frac{1}{T-1}ln\left(\frac{Y_{i,t+T}}{Y_{i,t}}\right) = \alpha + \beta ln(Y_{i,t}) + \gamma_1 ln(TII_{i,t}) + \gamma_2\left[ln(TII_{i,t})\right]^2 + c_1 cc_{i,t} + \cdots + \theta_t + \mu_i + \varepsilon_{i,t}. \{5\}$$

When $\gamma_1 > 0$ and $\gamma_2 < 0$, then the relationship between *TII* and growth is in the form of an inverted U-shaped letter, with a tipping point calculated as $\exp\{-\gamma_1/2\gamma_2\}$. Since the squared *TII* is considered as the interaction of *TII* with itself, the references provided about the analysis of conditional slope coefficients and their standard errors next to Eq. 3 and 4 are also relevant here.

Finally, combining Eq. 3 and 5, we can examine whether the absence of corruption shapes the non-linear relationship between *TII* and growth, that is, whether better government quality shifts the turning point after which transport infrastructure investments start to have a negative marginal effect on growth:

$$\frac{1}{T-1}ln\left(\frac{Y_{i,t+T}}{Y_{i,t}}\right) = \alpha + \beta ln(Y_{i,t}) + \gamma_1 ln(TII_{i,t}) + \gamma_2\left[ln(TII_{i,t})\right]^2 + \varphi_1 ln(TII_{i,t}) \times cc_{i,t} + \varphi_2\left[ln(TII_{i,t})\right]^2 \times cc_{i,t} + c_1 cc_{i,t} + \cdots + \theta_t + \mu_i + \varepsilon_{i,t}, \{6\}$$

Rearranging Eq. 6 to find the slope of growth on *TII*, we get:

$$\frac{1}{T-1}ln\left(\frac{Y_{i,t+T}}{Y_{i,t}}\right) = \alpha + \beta ln(Y_{i,t}) + \left[\gamma_1 + \gamma_2 ln(TII_{i,t}) + \varphi_1 cc_{i,t} + \varphi_2 ln(TII_{i,t}) \times cc_{i,t}\right] \times ln(TII_{i,t}) + c_1 cc_{i,t} + \cdots + \theta_t + \mu_i + \varepsilon_{i,t}, \{7\}$$

where expression in the brackets shows that the effect of *TII* on growth is conditional and depends on the level of *TII* and control of corruption simultaneously. The formulae for calculating standard errors associated with this conditional slope coefficient can be found in Butkus *et al.* (2020).

To measure the absence of corruption, we used the Worldwide Governance Indicators—Control of Corruption, provided by the World Bank. Following Kraay, Kaufmann and Mastruzzi (2010), we can argue that one of the aspects

of governance is "the capacity to effectively formulate and implement sound policies" related to the absence and control of corruption. According to Van de Walle and Migchelbrink (2020), "absence of corruption is the strongest government quality determinant," which directly affects "the odds of trust in public administration." The term 'control of corruption' can be defined as the perceptions of how public power is exercised for private gain. Seeking private and/or personal gain, low-quality governments might direct funds, including EU support, through corruption schemes, to unproductive infrastructure projects. For the robustness check, we will use regulatory quality as an alternative proxy for government quality.

We must estimate our equations by selecting the growth episode's span (T). Research that uses $T = 1$, i.e. annual per capita GDP growth (Saidi; Shahbaz & Akhtar, 2018; Batool & Goldman, 2020; Wang *et al.*, 2020; Chen *et al.*, 2021; Muvawala, Sebukeera & Ssebulime, 2021; Nenavath, 2021) maximizes the sample size. However, since *TII* only lagged by one period with respect to growth, this strategy might lead to estimates highly affected by the cyclical patterns of economic fluctuations and endogeneity. To address these issues, we set T equal to 5 (and to 3 in robustness check), aiming to estimate the effect of the current level of transport infrastructure investment (and other variables) on the 5-year forward-looking average growth rate of per capita GDP. Having a relatively short period under investigation instead of non-overlapping growth episodes, as an alternative, we use 5-year overlapping growth periods even though that creates a moving average structure in the error term. Following Panizza and Presbitero (2014), we use the Huber–White Sandwich correction, which yields almost identical results as Newey and West's (1987) estimator, which allows modelling of the autocorrelation in the error term.

Our panel includes unbalanced data for 27 EU countries. Cyprus is excluded due to missing data and the United Kingdom is a part of the sample. The period of analysis covers 2000–2019. Data is collected from Our World in Data, World Bank, and Eurostat databases. Table 1 presents the summary statistics of the research variables.

Table 1. Research variables and summary statistics.

Variables		Average	Min.	Max.	S. D.
	5-year average yearly growth rate, %	1.94	-6.95	10.8	2.59
Y	GDP per capita (constant 2,010 US$)	3.22×10^4	3.98×10^3	1.12×10^5	2.11×10^4
pop	Population, total	1.79×10^7	3.90×10^5	8.31×10^7	2.27×10^7
dens	Population density (people per sq. km of land area)	174	17	1.51×10^3	242
urb	Urban population (% of total population)	72.2	50.8	98.0	12.5
lf	Labor force, total	8.61×10^6	1.56×10^5	4.39×10^7	1.10×10^7
gcf	Gross capital formation (% of GDP)	22.9	11.9	46.0	4.56
opn	Trade (% of GDP)	117	45.4	408	64.9
fdi	Foreign direct investment, net inflows (% of GDP)	11.8	-58.3	449	38.2
gov	Total general government expenditure (% of GDP)	44.7	24.5	64.8	6.55
r&d_r	Researchers in R&D (per million people)	2.90×10^3	321	8.00×10^3	1.62×10^3
cpi	Consumer price index (2010 = 100)	96.8	32	124	13.5
hc	Tertiary educational attainment age group 30–34 (%)	33.5	7.4	58.8	11.8
cc	Control of Corruption: Estimate	1.03	-0.491	2.47	0.792
TII	Transport infrastructure investment (% of GDP)	1.07	0.576	0.00407	3.85
rq	Regulatory Quality: Estimate	1.20	-0.109	2.10	0.443

Source: Authors' calculations.

4. Results

Panel diagnostics revealed that country-fixed effects are present. Thus, all estimates include country dummies along with the time effects. Specifications were estimated using fixed effects to control for countries' unobserved heterogeneity. We present our main findings in Table 2.

Table 2. Fixed effects estimates of Eq. 1, 2, 3, 5, and 6. Dependent variable—5-year forward-looking average per capita GDP growth rate.

Full name of the regressor	Abbrev-iation	Para-meter	[1]	[2]	[3]	[4]	[5]
Transport infrastructure investment	ln(TII)	γ_1		0.0028**	-0.0059***	0.0048**	0.0051**
				(0.0013)	(0.0021)	(0.0018)	(0.0026)
Transport infrastructure investment × Control of corruption	ln(TII) × cc	φ_1			0.0107***		0.0023
					(0.0016)		(0.0029)
Squared transport infrastructure investment	$[\ln(TII)]^2$	γ_2				-0.0030***	-0.0029**
						(0.0004)	(0.0012)
Squared transport infrastructure investment × Control of corruption	$[\ln(TII)]^2$ × cc	φ_2					0.0019**
							(0.0001)
Control of corruption	cc	c_1	0.0122**	0.0083**	0.0106**	0.0081**	0.0102**
			(0.0053)	(0.0041)	(0.0050)	(0.0039)	(0.0049)
Population growth	Δln(pop)	c_2	-0.9613***	-0.6615***	-0.5472***	-0.4876**	-0.5331***
			(0.2097)	(0.2193)	(0.2042)	(0.2033)	(0.2005)
Population density	ln(dens)	c_3	0.0598**	0.0489*	0.0019	0.0277	0.0096
			(0.0287)	(0.0293)	(0.0281)	(0.0271)	(0.0272)
Urbanization level	ln(urb)	c_4	0.0250	0.0204	-0.0978*	0.0199	-0.0405
			(0.0539)	(0.0602)	(0.0586)	(0.0554)	(0.0581)
Growth of the labor force	Δln(lf)	c_5	0.1963***	0.2130***	0.2063***	0.1695***	0.1834***
			(0.0527)	(0.0513)	(0.0476)	(0.0476)	(0.0466)
Gross capital formation	gcf	c_6	0.0042***	0.0046***	0.0042***	0.0039***	0.0039***
			(0.0011)	(0.0011)	(0.0011)	(0.0011)	(0.0010)

Squared gross capital formation	gcf^2	c_7	-0.0001***	-0.0001***	-0.0001***	-0.0001***	-9.94e-05***
			(2.029e-05)	(2.135e-05)	(1.984e-05)	(1.968e-05)	(1.921e-05)
Openness to trade	ln(opn)	c_8	0.0597***	0.0606***	0.0353***	0.0520***	0.0394***
			(0.0109)	(0.0109)	(0.0109)	(0.0102)	(0.0106)
Foreign direct investment	fdi	c_9	-2.579e-05	1.142e-05	-8.119e-06	-6.987e-07	-1.442e-05
			(1.770e-05)	(2.061e-05)	(1.934e-05)	(1.904e-05)	(1.895e-05)
Government size	ln(gov)	c_{10}	-0.0235**	-0.0219*	-0.0336***	-0.0216**	-0.0229**
			(0.0119)	(0.0117)	(0.0110)	(0.0108)	(0.0111)
Research and development	ln(r&d)	c_{11}	-0.0029	-0.0017	-0.0007	0.0001	0.0004
			(0.0057)	(0.0057)	(0.0053)	(0.0053)	(0.0051)
Inflation	Δln(cpi)	c_{12}	0.0076	0.0083	0.0038	-0.0007	-0.0019
			(0.0397)	(0.0394)	(0.0365)	(0.0362)	(0.0354)
Human capital	ln(hc)	c_{13}	0.0076	-0.0009	0.0081	0.0075	0.0119**
			(0.0059)	(0.0059)	(0.0057)	(0.0056)	(0.0056)
GDP per capita	ln(Y)	β	-0.0127***	-0.0115***	-0.0148***	-0.0132***	-0.0146***
			(0.0015)	(0.0015)	(0.0015)	(0.0014)	(0.0015)
Intercept		α (0.4126)	0.6846*	0.6346	1.827***	0.9182**	1.444***
			(0.4321)	(0.4387)	(0.3997)	(0.4331)	
Number of observations			342	325	325	325	325
Within R^2			0.7854	0.7992	0.8278	0.8306	0.8399
Pesaran CD test for cross-sectional dependence(1) [p-value]			[0.1979]	[0.2113]	[0.1999]	[0.2192]	[0.1919]
Test for differing group intercepts(2) [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]
Wald joint test on time dummies(3) [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]
Hausman test(4) [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]	[<0.001]
Wooldridge test(5) [p-value]			[0.1438]	[0.154]	[0.1731]	[0.196]	[0.1472]

Note: (1) A low p-value counts against the null hypothesis: cross-sectional independence. (2) A low p-value counts against the null hypothesis: the groups have a common intercept. (3) A low p-value counts against the null hypothesis: no time effects. (4) A low p-value counts against the GLS estimates with random effects in favor of LSDV. (5) A low p-value counts against the null hypothesis: no first-order serial correlation in error terms. Heteroscedasticity robust standard errors are presented in parentheses. All estimations include time- and country-fixed effects, and Huber-White Sandwich correction. *, **, *** indicate significance at the 10, 5 and 1 per cent level, respectively.

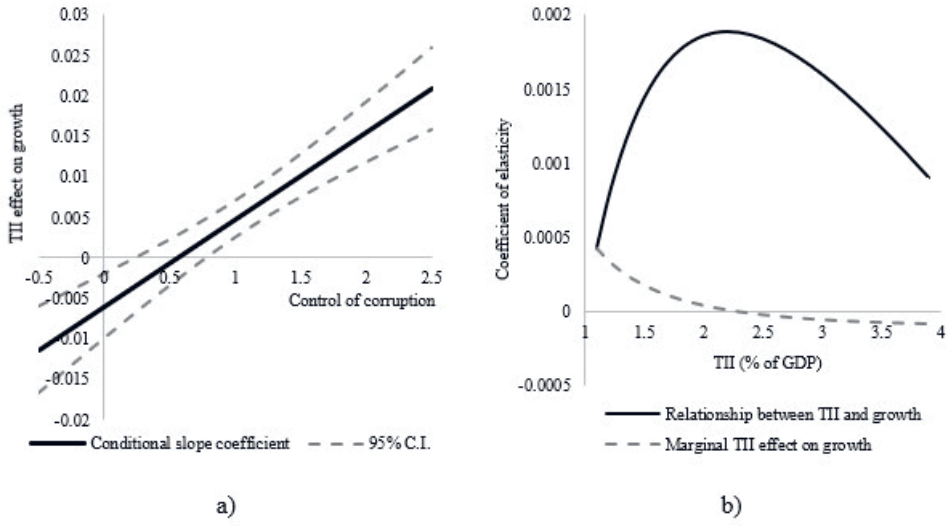
Source: Authors' calculations.

The estimated coefficients on control variables have a theoretically justified impact on growth and are consistent with previous research. For example, lower corruption is related to a higher growth rate when other growth factors are equal. The negative coefficient on initial per capita GDP specifies that less developed EU MS have faster growth rates and are catching up with developed ones. Still, they converge only at the rate below "the legendary 2 per cent" (Abreu *et al.*, 2005). The results of estimations revealed that trade openness and labor force growth positively correlate with GPD per capita growth, while population growth and a bigger government harm growth. We also find evidence of an inverted U-shaped form of the relationship between capital and growth. It is consistent with the neoclassical theory of diminishing marginal growth outcomes of capital investments. According to estimations, once TII reaches a threshold level of approximately 19–21%, it does not generate positive returns. Considering the transport infrastructure investment, we find that linear specification (Eq. 2) reveals the positive and statistically significant relationship between *TII* and growth (see estimation [2] in Table 2). However, the estimated coefficient of elasticity shows a rather small effect of TII on growth, that is, an increase of investment by 1% would boost economic growth additionally by 0.003%.

Estimation of specification, which considers the absence of corruption as a possible moderator of the effect that *TII* has on growth (Eq. 3), shows that control of corruption plays a significant role in *TII*-growth nexus (see estimation [3] in Table 2). Figure 1a shows that control of corruption considerably changes this relationship.

We find that in countries with a level of control of corruption below 0.2, *TII* has a negative and statistically significant effect on growth. One possible explanation is that TII are spent inefficiently in relatively corrupted countries, and growth opportunities are lost. Such a low level of control of corruption is typical for Bulgaria, Croatia, Greece, Romania, and partially for Italy, Lithuania, Latvia, Hungary, and Slovakia. If the control of corruption is above 0.2, but below 0.8, the estimated effect of *TII* on growth is insignificant. This level of corruption is typical to the Czech Republic, Italy, Hungary, Lithuania, Latvia, Poland, Slovakia, and partially to Slovenia, Spain, and Malta. The level of control of corruption equal to or above 0.8 is related to the statistically significant positive effect of *TII* on growth. This level of corruption is typical for Austria, Germany, Belgium, Ireland, Denmark, Estonia, France, Finland, Malta, Luxembourg, the Netherlands, Portugal, Spain, Slovenia, Sweden, and the United Kingdom.

Figure 1. The relationship between transport infrastructure investment and growth. **a)** Effect of TII on growth is moderated by control of corruption. Visualization is based on Eq. 4 and estimation [3] in Table 2. **b)** Effect of TII on growth is moderated by the size of *TII*, i.e. relationship between *TII* and growth is non-linear. Visualization is based on Eq. 5 and estimation [4] in Table 2

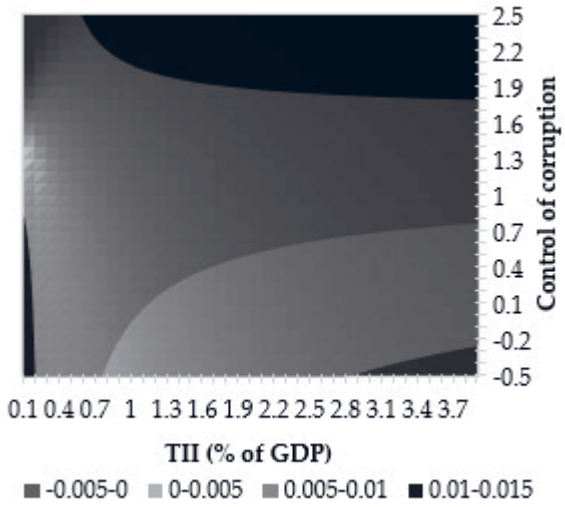


Source: Composed by the authors.

Estimates of the non-linear specification in Eq. 5 revealed that the turning point of the direction of *TII*-growth nexus is at about 2.2% of *TII* to GDP ratio (see estimation [4] in Table 2 and Fig. 1b). The TII above this level is associated with slowing down economic growth. We find that such a high level of *TII* to GDP ratio is in Croatia and Romania. This was also proper for Bulgaria, Greece, the Czech Republic, Hungary, Poland, and Latvia for one or two years. After considering that in Romania and Croatia, the level of control of corruption is very low, TII in these countries are indeed negatively associated with growth.

Modelling of the non-linear *TII*-growth relationship, which is moderated by the quality of institutions based on the specification in Eq. 6, is presented in estimation [5] in Table 2. The analysis shows (see Fig. 2) that a high level of control of corruption can shift the threshold in the *TII*-growth relationship to the right. It means that high rates of *TII* to GDP can still be positively related to economic growth if the absence of corruption is sufficient enough to direct these investments to growth-enhancing projects.

Figure 2. The conditional non-linear *TII*-growth relationship moderated by control of corruption. Modelling of the composite conditional slope of growth on *TII* is based on Eq. 7 and estimation [5] in Table 2.



4.1 Robustness check

A robustness check of our results is performed in several directions. First, we can assume that transport infrastructure investments could overlap with investments of the private sector and government expenditures, which we used to proxy the size of the government. We re-estimated all our specifications omitting these factors (see results in Table A1 in the Appendix). Estimations are in line with the general findings—*TII* has a positive effect on growth but the size of the effect is even smaller (see estimation [6]), despite the fact that it is within the range of 95% confidence interval of the estimated elasticity from the general estimation. We also found that the absence of corruption changes the direction of the TII-growth relationship significantly, regardless of slightly different intervals for negative and statistically significant effects (see Table 3). The findings also confirm the non-linear nature of the relationship between TII and growth, with the estimated turning point of this relationship at about 1.7% of TII to GDP ratio. Being lower than in the general estimation, it suggests that more countries are above this threshold level when the marginal effect of TII is not positive anymore. Thus, Croatia and Romania now are accompanied by Spain, Slovenia, Hungary, and Bulgaria.

Table 3. Effect of TII on growth depending on the quality of institutions.

Proxy for absence of corruption	Based on estimation	Effect of TII on growth		
		Negative and statistically significant	Statistically insignificant	Positive and statistically significant
Control of corruption	[3]	[-0.5, 0.2]	(0.2, 0.7]	(0.7, 2.5]
	[7]	[-0.5, -0.1]	(-0.1, 0.6]	(0.6, 2.5]
	[13]	[-0.5, 0.0]	(0.0, 0.9]	(0.9, 2.5]
Regulatory quality	[10]	[-0.1, 0.7]	(0.7, 1.0]	(1.0, 2.1]

Second, as the alternative proxy for the absence of corruption, we used regulatory quality instead of control of corruption and re-estimated Eq. 3 and 6. The results are presented in Table A2 (see Appendix). Results, in general, remain the same—better institutions lead to positive and statistically significant growth outcomes of TII (see Table 3) and shift the turning point of the inverted U-shaped form of relationship between TII and growth to the right, that is, the negative marginal effect of TII is less plausible when the institutional environment is more favourable.

Finally, as the alternative dependent variable, we used 3-year overlapping growth periods (see the results in Table A3 in the Appendix). Estimations match with the general ones.

5. Conclusions and discussion

Summarising the results of previous contributions we can state that: (i) transport infrastructure investment has a heterogeneous impact on economic growth; (ii) most researches identify a linear relationship between transport infrastructure investments and economic growth, although non-linear effects may occur; and (iii) little attention is drawn on the effects of corruption on economic results of transportation investment. Our contribution to previous research was to examine linear and non-linear impact of transport infrastructure investments on economic growth in EU countries, as well as to investigate the mediating effect of absence of corruption on those outcomes.

Our results confirm a positive and statistically significant linear relationship between TII and economic growth when applying a linear specification, in line with Crescenzi and Rodríguez-Pose (2012); Lenz, Skender and Mirković

(2018), Cigu *et al*. (2019), Wang *et al*. (2020), Muvawala, Sebukeera and Ssebulime (2021), Batool and Goldmann (2021), Elburz and Cubukcu (2021), and Alotaibi *et al*. (2021). Non-linear specification revealed a diminishing trend of the transport investment impact on economic growth, and the transport infrastructure investment above the threshold level is associated with slowing economic growth. More control intensity has to implemented in the countries (i.e., Croatia, Romania, Bulgaria, the Czech Republic, Greece, Hungary, Latvia, and Poland), where investment in transport exceeds the threshold level.

The results also indicate that the outcomes of the transport infrastructure depend on the absence of corruption measured as corruption control, as it was stated in the studies by Crescenzi *et al*. (2016), Fazekas and Tóth (2018), Kyriacou, Muinello-Gallo and Roca-Sagalés (2019), and Cigu *et al*. (2019). A low level of corruption control is associated with lower or even negative impact of transport infrastructure investment on economic growth. The focus should be on reducing corruption in Croatia and Romania, as the results show a negative impact of *TII* on the economic growth in these countries. In 2019, according to control of corruption, Croatia ranked 24th among EU MS and Romania ranked 27th. Significant attention needs to be paid to the management of corruption in countries where corruption control levels have significantly decreased, a situation compared in 2019 with 2020: Hungary, Malta, Spain, Greece, Cyprus, and Italy. In these countries, declining control of corruption can lead to inefficient allocation and the use of other investments and resources.

Our analysis indicates the need for improving transport infrastructure policies and the allocation of national and European structural funds, particularly in the countries which exceed the threshold level of transport infrastructure investment. However, our estimation included only the total amount of transport infrastructure investments, but it also would be useful to examine the impact of specific transport infrastructure (road, rail, air) investments on economic growth, and this could be addressed in future research.

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Appendix

Table A1. Fixed effects estimates of Eq. 2, 3, 5, and 6 without private sector investments and government size. Dependent variable—5-year forward-looking average per capita GDP growth rate.

The name of regressor		Para-meter	[6]	[7]	[8]	[9]
Full	Short					
Transport infrastructure investment	ln(TII)	γ_1	0.0024**	-0.0042**	0.0032**	0.0054**
			(0.0012)	(0.0019)	(0.0015)	(0.0027)
Transport infrastructure investment × Control of corruption	ln(TII) × cc	φ_1		0.0103***		0.0006
				(0.0017)		(0.0029)
Squared transport infrastructure investment	$[\ln(TII)]^2$	γ_2			-0.0030***	-0.0019**
					(0.0005)	(0.0008)
Squared transport infrastructure investment × Control of corruption	$[\ln(TII)]^2$ ×cc	φ_2				0.0027***
						(0.0010)
Control of corruption	cc	c_1	0.0098*	0.0110**	0.0098*	0.0117**
			(0.0054)	(0.0051)	(0.0051)	(0.0050)
Population growth	Δln(pop)	c_2	-0.2758	-0.1190	-0.1361	-0.2062
			(0.2150)	(0.2044)	(0.2021)	(0.2024)
Population density	ln(dens)	c_3	0.0008	0.0449	0.02863	0.04015
			(0.0286)	(0.0279)	(0.0270)	(0.0270)
Urbanization level	ln(urb)	c_4	0.0979	0.2035***	0.1008*	0.1500**
			(0.0601)	(0.0592)	(0.0562)	(0.0584)
Growth of the labor force	Δln(lf)	c_5	0.1187**	0.1198**	0.0729	0.0925*
			(0.0511)	(0.0482)	(0.0483)	(0.0473)
Openness to trade	ln(opn)	c_8	0.0693***	0.0465***	0.0606***	0.0480***
			(0.0113)	(0.0113)	(0.0107)	(0.0109)
Foreign direct investment	fdi	c_9	1.623e-05	3.830e-06	1.139e-07	1.469e-05
			(2.097e-05)	(2.005e-05)	(1.976e-05)	(1.959e-05)
Research and development	ln(r&d)	c_{11}	0.0038	0.0028	0.0007	0.0009
			(0.0057)	(0.0053)	(0.0053)	(0.0052)

Inflation	Δln(cpi)	c_{12}	-0.0432	-0.0380	-0.0547	-0.0524
			(0.0393)	(0.0371)	(0.0368)	(0.0360)
Human capital	ln(hc)	c_{13}	0.0019	0.0104*	0.0104*	0.0154**
			(0.0063)	(0.0061)	(0.0059)	(0.0060)
GDP per capita	ln(Y)	β	-0.0140***	-0.0170***	-0.0162***	-0.0172***
			(0.0014)	(0.0015)	(0.0014)	(0.0014)
Intercept		α (0.4121)	1.558***	2.595***	1.909***	2.325***
			(0.4244)	(0.3889)	(0.4138)	
Number of observations			338	338	338	338
Within R^2			0.7665	0.7932	0.7967	0.8084
Pesaran CD test for cross-sectional dependence(1) [p-value]			[0.2113]	[0.1999]	[0.2192]	[0.1919]
Test for differing group intercepts(2) [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]
Wald joint test on time dummies(3) [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]
Hausman test(4) [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]
Wooldridge test(5) [p-value]			[0.154]	[0.1731]	[0.196]	[0.1472]

Note: (1) A low p-value counts against the null hypothesis: cross-sectional independence. (2) A low p-value counts against the null hypothesis: the groups have a common intercept. (3) A low p-value counts against the null hypothesis: no time effects. (4) A low p-value counts against the GLS estimates with random effects in favor of LSDV. (5) A low p-value counts against the null hypothesis: no first-order serial correlation in error terms. Heteroscedasticity robust standard errors are presented in parentheses. All estimations include time- and country-fixed effects, and Huber-White Sandwich correction. *, **, *** indicate significance at the 10, 5 and 1 per cent level, respectively.

Table A2. Fixed effects estimates of Eq. 3 and 6. Dependent variable—5-year forward-looking average per capita GDP growth rate. Proxy for absence of corruption—regulatory quality.

Full name of the regressor	Short name of the regressor	Parameter	[10]	[11]
Transport infrastructure investment	ln(TII)	γ_1	-0.0152***	0.0135***
			(0.0030)	(0.0048)
Transport infrastructure investment × Regulatory quality	ln(TII) × rq	φ_1	0.0160***	0.0099**
			(0.0022)	(0.0045)
Squared transport infrastructure investment	$[\ln(TII)]^2$	γ_2		-0.0015***
				(0.0005)

Squared transport infrastructure investment × Regulatory quality	$[\ln(TII)]^2 \times rq$	φ_2		0.0027**
				(0.0014)
Regulatory quality	rq	c_1	0.0198***	0.0198***
			(0.0057)	(0.0056)
Population growth	Δln(pop)	c_2	-0.5428***	-0.5147**
			(0.1995)	(0.1986)
Population density	ln(dens)	c_3	0.0046	0.0115
			(0.0264)	(0.0264)
Urbanization level	ln(urb)	c_4	0.0066	0.0232
			(0.0548)	(0.0541)
Growth of the labor force	Δln(lf)	c_5	0.1964***	0.1751***
			(0.0460)	(0.0457)
Gross capital formation	gcf	c_6	0.0033***	0.0032***
			(0.0010)	(0.0010)
Squared gross capital formation	gcf^2	c_7	-8.951e-05***	-8.897e-05***
			(1.932e-05)	(1.901e-05)
Openness to trade	ln(opn)	c_8	0.0352***	0.0405***
			(0.0106)	(0.0107)
Foreign direct investment	fdi	c_9	7.519e-06	4.071e-06
			(1.838e-05)	(1.842e-05)
Government size	ln(gov)	c_{10}	-0.0266**	-0.0243**
			(0.0105)	(0.0107)
Research and development	ln(r&d)	c_{11}	0.0029	0.0040
			(0.0053)	(0.0052)
Inflation	Δln(cpi)	c_{12}	-0.0194	-0.0151
			(0.0356)	(0.0350)
Human capital	ln(hc)	c_{13}	0.0103*	0.0116**
			(0.0055)	(0.0055)
GDP per capita	ln(Y)	β	-0.0142***	-0.0143***
			(0.0014)	(0.0013)
Intercept		α (0.3923)	1.238***	1.109***
			(0.3891)	

Number of observations	325	325
Within R^2	0.8394	0.8461
Pesaran CD test for cross-sectional dependence(1) [p-value]	[0.1999]	[0.1919]
Test for differing group intercepts(2) [p-value]	[<0.001]	[<0.001]
Wald joint test on time dummies(3) [p-value]	[<0.001]	[<0.001]
Hausman test(4) [p-value]	[<0.001]	[<0.001]
Wooldridge test(5) [p-value]	[0.1731]	[0.1472]

Note: (1) A low p-value counts against the null hypothesis: cross-sectional independence. (2) A low p-value counts against the null hypothesis: the groups have a common intercept. (3) A low p-value counts against the null hypothesis: no time effects. (4) A low p-value counts against the GLS estimates with random effects in favor of LSDV. (5) A low p-value counts against the null hypothesis: no first-order serial correlation in error terms. Heteroscedasticity robust standard errors are presented in parentheses. All estimations include time- and country-fixed effects, and Huber-White Sandwich correction. *, **, *** indicate significance at the 10, 5 and 1 per cent level, respectively.

Table A3. Fixed effects estimates of Eq. 2, 3, 5, and 6. Dependent variable—3-year forward-looking average per capita GDP growth rate.

The name of regressor		Parameter	(12)	(13)	(14)	(15)
Full	Short					
Transport infrastructure investment	ln(TII)	γ_1	0.0030**	-0.0069**	0.0073**	0.0044
			(0.0016)	(0.0033)	(0.0029)	(0.0042)
Transport infrastructure investment × Institutions	ln(TII) × inst_cc	φ_1		0.0114***		0.0023
				(0.0026)		(0.0045)
Squared transport infrastructure investment	$[\ln(TII)]^2$	γ_2			-0.003689***	-0.0012
					(0.0006827)	(0.0020)
Squared transport infrastructure investment × Institutions	$[\ln(TII)]^2$ × inst_cc	φ_2				0.0035**
						(0.0015)
Institutions (Control of corruption)	inst_cc	c_1	0.0179**	0.0203**	0.0177**	0.0200**
			(0.0084)	(0.0081)	(0.0079)	(0.0079)
Population growth	Δln(pop)	c_2	-1.129***	-1.008***	-0.9166***	-1.013***
			(0.3397)	(0.3301)	(0.3258)	(0.3257)
Population density	ln(dens)	c_3	0.0935**	0.0437	0.0674	0.0559
			(0.0454)	(0.0454)	(0.0435)	(0.0442)
Urbanization level	ln(urb)	c_4	0.0960	0.2209**	0.0964	0.1357
			(0.0933)	(0.0948)	(0.0889)	(0.0944)

Growth of the labor force	Δln(lf)	c_5	0.2118***	0.2046***	0.1585**	0.1739**
			(0.0795)	(0.0770)	(0.0763)	(0.0756)
Gross capital formation	gcf	c_6	0.0065***	0.0060***	0.0057***	0.0057***
			(0.0018)	(0.0017)	(0.0017)	(0.0017)
Squared gross capital formation	gcf^2	c_7	-0.0001***	-0.0001***	-0.0001***	-0.0001***
			(3.308e-05)	(3.208e-05)	(3.155e-05)	(3.121e-05)
Openness to trade	ln(opn)	c_8	0.1068***	0.0799***	0.0962***	0.0856***
			(0.0170)	(0.0176)	(0.0163)	(0.0172)
Foreign direct investment	fdi	c_9	5.175e-06	1.550e-05	9.645e-06	2.697e-05
			(3.193e-05)	(3.127e-05)	(3.052e-05)	(3.079e-05)
Government size	ln(gov)	c_{10}	-0.0777***	-0.0901***	-0.0774***	-0.0727***
			(0.0182)	(0.0178)	(0.0173)	(0.0181)
Research and development	ln(r&d)	c_{11}	0.0035	0.0046	0.0058	0.0063
			(0.0088)	(0.0086)	(0.0084)	(0.0083)
Inflation	Δln(cpi)	c_{12}	-0.1929***	-0.1977***	-0.2039***	-0.2064***
			(0.0610)	(0.0590)	(0.0580)	(0.0575)
Human capital	ln(hc)	c_{13}	0.0143	0.0047	0.0041	0.0014
			(0.0092)	(0.0092)	(0.0090)	(0.0091)
GDP per capita	ln(Y)	β	-0.0153***	-0.0189***	-0.0175***	-0.0185***
			(0.0024)	(0.0024)	(0.0023)	(0.0024)
Intercept		α (0.6696)	1.278*	2.540***	1.625**	1.956***
			(0.7093)	(0.6406)	(0.7036)	
Number of observations			325	325	325	325
Within R^2			0.7649	0.7805	0.7878	0.7940
Pesaran CD test for cross-sectional dependence[(1)] [p-value]			[0.2113]	[0.1999]	[0.2192]	[0.1919]
Test for differing group intercepts[(2)] [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]
Wald joint test on time dummies[(3)] [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]
Hausman test[(4)] [p-value]			[<0.001]	[<0.001]	[<0.001]	[<0.001]
Wooldridge test[(5)] [p-value]			[0.154]	[0.1731]	[0.196]	[0.1472]

Note: [(1)] A low p-value counts against the null hypothesis: cross-sectional independence. [(2)] A low p-value counts against the null hypothesis: the groups have a common intercept. [(3)] A low p-value counts against the null hypothesis: no time effects. [(4)] A low p-value counts against the GLS estimates with random effects in favor of LSDV. [(5)] A low p-value counts against the null hypothesis: no first-order serial correlation in error terms. Heteroscedasticity robust standard errors are presented in parentheses. All estimations include time- and country-fixed effects, and Huber-White Sandwich correction. *, **, *** indicate significance at the 10, 5 and 1 per cent level, respectively.