WEP Warwick Evans Publishing

International Journal of Social Sciences and Public Administration

ISSN: 3005-9836 (Print), ISSN: 3005-9585 (Online) | Volume 6, Number 2, Year 2025
DOI: https://doi.org/10.62051/ijsspa.v6n2.20
Journal homepage: https://ijsspa.org

The Impact of Transportation Infrastructure on Green Total Factor Productivity

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ABSTRACT

This study examines the effect of transportation infrastructure on Green Total Factor Productivity (GTFP) across 50 countries from 2001 to 2021. Using a non-radial, non-oriented Slacks-Based Measure (SBM) to measure GTFP and explores the impact of infrastructure development. Results show that transportation infrastructure positively contributes to GTFP. Other key factors, including foreign direct investment (FDI), urbanization, government intervention, and R&D investment, also significantly influence GTFP. The findings suggest that tailored infrastructure and policies are crucial for maximizing green development.

KEYWORDS

Green Total Factor Productivity; Transportation Infrastructure; FDI.

1. INTRODUCTION

The transportation sector plays a crucial role in supporting economic development and green production initiatives. Investments in transportation infrastructure have a complex and dynamic influence on economic systems with a time lag between the investment and the realised economic benefits[1]. Transportation infrastructure has made significant multifaceted effects on all range of economic sectors that include agriculture, manufacture and industry and service[3]. Transportation infrastructure is not just foundation of economic growth, but with its further improvement and extension to marginal rural area, it can boost the economic development and improve the social welfare for the poor [4].

However, whether transportation infrastructure can maxmise its positive impact on sustainable economic development has been always vary. In many developing countries, transportation infrastructure was conducted due to personal agenda and corruption but ignored its business adaptation and integration with local economy [5].

Despite there is possible contradictory outcome between infrastructure development and emerging environment issues, developing countries have been putting transportation infrastructure as the priority, whilst developed countries have started to upgrade their aging transportation system. Therefore, it's important to understand if transportation system has impacted on economic development efficiently.

2. LITERATURE REVIEW

Sustainable infrastructure on transportation system required to meet current mobility necessity and bring efficient economic development without compromising the ability of future generation to meet their own needs[6].

However, the relationship between transportation infrastructure and GTFP is not always straightforward. Wang et al. discovered that while road density initially improved GTFP, excessive road construction could lead to diminishing returns and even negative impacts due to increased pollution and resource consumption[7]. It is interesting to find that there was a U-shaped relationship between economic development and GTFP[8] which shows similar pattern with the relationship between road construction and GTFP based on above study [9].

Environmental aspect has accounted as one of the key measurements for sustainable infrastructure development in recent studies. Greenhouse gas (GHG) emissions and energy consumption are critical environmental indicators for sustainable transportation. Creutzig et al. explored the relationship between urban form and GHG emissions[10].

In addition, types of investments have indicated its various levels that impact on infrastructure-GTFP. FDI tend to have positive effect on GTFP. Wu et al. also found that positive effect of investment on GTFP can be further enhanced, however, this is in condition of if the institutional quality improves, and it did not find that Chinese outward direct investment (ODI) have a pollution shelter effect[11]. This study is to investigate if transportation system in BRI countries can improve GTFP.

3. MEASUREMENT OF GTFP

3.1. Measurement Method

Fukuyama and Weber combined the SBM model with the directional distance function to form the non-radial, non-oriented directional distance function SBM-DDF based on slack measurement[12]. Building on this, Yang et al. proposed treating CO2 as an undesirable output rather than an input production factor[13]. Therefore, this study, utilizing a combination of SBM and DDF models, examines the green total factor productivity (GTFP) in Belt and Road Initiative (BRI) countries from 2001 to 2021.

3.2. Indicator Selection

Considering relevant data availability, and indicators that have applied by previous researches, this paper adopts the following measures and the the specific input and output indicators are given as follows: Labor Input and capital input from world bank; resource input from US energy information administration, and expected output such as GDP from world bank and unexpted output is from global carbon budget.

3.3. Results Analysis

Using selected input-output indicators, the GML index was calculated for 50 countries from 2001 to 2021. This index reflects the annual rate of change in Green Total Factor Productivity (GTFP) relative to the previous year. To establish a baseline, GTFP for the year 2000 was set to 1, and subsequent values from 2001 to 2021 were determined by sequentially multiplying the corresponding GML indices. This approach enabled a comprehensive assessment of GTFP trends over two decades. The findings of this analysis are presented in Table 1 below.

Table 1. GTFP result between 2001- 2021

Year	GTFP
2001	1.00
2002	1.00
2003	0.99
2004	0.99
2005	0.99
2006	0.99
2007	0.99
2008	0.99
2009	1.00
2010	1.01
2011	1.01
2012	1.01
2013	1.02
2014	1.03
2015	1.03
2016	1.04
2017	1.04
2018	1.04
2019	1.05
2020	1.06
2021	1.08
Mean	1.02

As shown in Table 1, the overall status of GTFP development in countries along the BRI is generally positive, exhibiting a growth trend. During the period from 2001 to 2021, the average GTFP value was 1.02, indicating that BRI countries are increasingly emphasizing green economic development, with an overall positive trajectory.

4. RESEARCH DESIGN

4.1. Empirical Method for Transport Infrastructure on GTFP

The following outlines the basic econometric model design used in the analysis:

$$GTFP_{i,t} = \alpha_0 + \beta_1 Rail_{i,t} + \beta_2 Road_{i,t} + \sum_{j=5}^{n} \theta_j X_{i,t} + \mu_i + \gamma_t + \varepsilon_{i,t} \tag{1}$$

Where i and t represent the countries and years within the study sample respectively. β_1 and β_2 are their respective coefficients to be estimated. If β_1 is significant and greater than 0, it indicates that railway density has promoted the growth of GTFP in countries along the BRI; if β_1 is significant and less than 0, the opposite is true. The same logic applies to β_2.

4.2. Variable Selection

GTFP is influenced not only by transportation infrastructure but also by factors such as investment, policies, innovations, and industrial structure. This paper uses GTFP as the explained variable, with railway density and road density as explanatory variables, while also considering factors such as FDI, urbanization, government intervention, R&D investment, and industrial structure as control variables.

Considering the availability and stability of statistical data, the study period is set from 2001 to 2021. The data for the variables are sourced from the World Bank Database, the International Road Federation, and the "Statistical Yearbooks" of various countries. Due to significant data gaps in some countries, this study focuses on 50 countries along the BRI as the research sample. Additionally, for any missing data, linear interpolation was employed to fill in the gaps.

4.3. Results and Discussions

Table 2. Findings of Transport Infrastructure on GTFP

	(1)	(2)	(3)	(4)	(5)	(6)
	GTFP	GTFP	GTFP	GTFP	GTFP	GTFP
Rail	0.0118***	0.0122***	0.0152***	0.0117***	0.0153***	0.0131***
	(4.9026)	(5.4599)	(4.9565)	(4.9154)	(5.4413)	(5.0465)
Road	0.0004**	0.0005**	0.0007***	0.0006***	0.0007**	0.0005**
	(2.0632)	(2.4257)	(3.0658)	(3.2040)	(2.5369)	(2.3347)
FDI		-0.0029***	-0.0015***	-0.0028***	-0.0019***	-0.0027**
		(-5.3573)	(-5.3112)	(-5.1574)	(-5.2757)	(-5.1418)
Urban			-0.0025**	-0.0031*	-0.0026**	-0.0023**
			(-2.3252)	(-1.9501)	(-2.2603)	(-2.2644)
Gov				-0.0041***	-0.0052***	-0.0055***
				(-4.3416)	(-4.3459)	(-4.6837)
RD					0.0438**	0.0386***
					(4.0851)	(3.6266)
Stru						-0.0021***
						(-5.3429)
_cons	0.8312***	0.9514***	1.0657**	1.1319***	1.1231***	1.2254**
	(59.2884)	(58.1218)	(18.8659)	(19.5232)	(19.5827)	(20.4919)
N	1021	1021	1021	1021	1021	10521
adj. R^2	0.112	0.125	0.121	0.156	0.161	0.183

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$. Robust t-statistics in parentheses, calculated based on standard errors clustered by country. All models include dummies for year and country.

Based on the Hausman test and the F-test, we selected the fixed-effects model to examine the impact of transportation infrastructure on GTFP. We performed regressions on the explanatory variables (Rail, Road) in models. Subsequently, control variables (FDI, Urban, Gov, RD, Stru) were gradually added and regressed separately. The regression results are shown in Table 2.

As Table 2 shows, when control variables are not included, transportation infrastructure has a significantly positive effect on GTFP in BRI countries, indicating that transportation infrastructure contributes to the improvement of GTFP. After sequentially adding control variables, transportation infrastructure continues to exert a significant positive influence on GTFP, suggesting that, even when accounting for other factors, transportation infrastructure maintains a stable effect on green development. This enhances the scientific accuracy of the regression results.

Table 2 reveals that FDI significantly hinders the growth of GTFP. Although this influx of foreign direct investment can promote short-term economic expansion, the resulting pollution not only offsets potential productivity gains, but also weakens long-term sustainability. As pollution increases, it further suppresses the growth of GTFP. Urbanization significantly hinders GTFP by intensifying environmental pressures. As cities expand, shifts in lifestyles and production methods drive higher resource consumption and waste generation. Increased population density, along with evolving living and industrial practices, leads to greater emissions and pollution, further straining ecological systems. These environmental constraints weaken sustainability and diminish productivity growth. Consequently, while urbanization fosters economic activity, it also imposes long-term ecological challenges that reduce GTFP. Addressing these issues requires sustainable urban planning, improved resource management, and policies that balance development with environmental protection.

5. SUMMARY

Using a combination of SBM and DDF, this study examines the impact of transportation infrastructure on green total factor productivity (GTFP) in BRI countries from 2001 to 2021. Findings highlight that railway and highway density significantly contribute to GTFP, though their effects depend on economic development levels and infrastructure quality.

Additional factors, including FDI, urbanization, government intervention, R&D investment, and industrial structure, also influence GTFP, with varying effects. The study underscores key policy implications: while infrastructure development promotes green growth, excessive expansion may lead to environmental degradation and resource overuse, particularly in less developed economies. Local governments should balance transportation investments with sustainability considerations to optimize GTFP benefits. This research enhances understanding of transportation infrastructure's role in green growth and stresses the need for tailored policies suited to each country's economic and environmental context.

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