IOSR Journal Of Humanities and Social Science (IOSR-JHSS)
Volume 31, Issue 8, Series 1 (August, 2026) 01-11
e-ISSN: 2279-0837, p-ISSN: 2279-0845.
www.iosrjournals.org

Effects Of Public Investments In Road Infrastructure On Economic Growth In The Republic Of Congo

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Abstract:
The main objective of this work was to analyze the effects of public investments in road infrastructure on economic growth in the Congo. After exploring the economic literature on growth, we went straight on to line of Barro theory that infrastructure is the endogen of long-term economic growth. To this end, we have resorted to an erro-correction model to analyze annual datas covering the period from 1985 to 2023.
After estimations, the econometric regression reveals that investments in road infrastructure have a positive and significative effect on long-term economic growth. The results of our estimations also show that, in the long-term, aside from investments in road infrastructure, the private investments have a positive effect on economic growth in the Congo.
Key Word: *Public investment, road infrastructure, economic growth.*
Date of Submission: 24-07-2026 Date of Acceptance: 04-08-2026

I. Introduction

Economic growth is one of the main objectives of national economic policy and remains a major concern for both economists and policymakers (Bakari and Mabrouki, 2018). From the seminal work of Solow (1956) to the endogenous growth models developed by Romer (1986) and Lucas (1988), several determinants of economic growth have been identified, among which public investment in infrastructure plays an increasingly important role (Barro, 1990; World Bank, 1994). Road infrastructure, by facilitating the mobility of people and goods, reduces transport costs, improves business productivity, and strengthens market integration, thereby promoting economic growth (Aschauer, 1989; Berkane, 2013).

In the global context, economic growth has slowed in recent years, falling from nearly 4% in 2017 to 3.3% in 2019 due to declining investment, reduced trade, and weak global demand (AfDB, 2019). In sub-Saharan Africa, where growth is largely dependent on the exploitation of natural resources, this situation remains a concern (UNCTAD, 2012). On average, economic growth in sub-Saharan Africa declined by 5.6% between 2000 and 2016 (African Union Commission/OECD, 2018). This deterioration is attributed to low commodity prices. Furthermore, between 2017 and 2018, growth increased from 1.1% in 2017 to 2.2% in 2018 (AfDB, 2019) following the rise in commodity prices, particularly oil. In the Republic of Congo, the economy remains heavily dependent on oil, and fluctuations in international prices have led to a slowdown in growth, from 6.8% in 2014 to -5% in 2020 (World Bank, 2017; BEAC, 2020). Faced with this vulnerability, Congolese authorities have made investments in road infrastructure a strategic lever for economic diversification and development.

To this end, the Congo has undertaken several public investment programs aimed at improving its road network, notably through the Five-Year Plan (1982-1986), the Accelerated Municipalization Program (2004-2016), and the National Transport Plan (Etsiba, 2018). These efforts have increased the national road network from 14,522 km in 2000 to 23,234 km in 2017, while the length of paved roads increased from 1,212 km (8.34%) to 3,111 km (13.04%) during the same period. Despite this progress, the contribution of road infrastructure to economic growth remains insufficient, raising questions about its actual effectiveness in the Congolese context.

The relationship between road infrastructure investment and economic growth is theoretically controversial. On the one hand, endogenous growth theories developed by Barro (1990), d'Aschauer (1989), and Munnell (1990) argue that public infrastructure investment generates positive externalities, stimulates productivity, and promotes sustainable economic growth. On the other hand, some authors, notably Nadiri and Mamuneas (1996), Waters (1999), and Khanam (1999), qualify this relationship, suggesting that the effects of infrastructure on growth depend on its quality, economic efficiency, financing methods, and the institutional context.

Empirically, the results remain mixed. One school of thought, represented notably by Aschauer (1989), Munnell (1990), and Barro (1990), highlights a positive effect of road infrastructure investments on economic growth. Conversely, a second school of thought, illustrated by Nadiri and Mamuneas (1996), Waters (1999), and Khanam (1999), concludes that the effects are weak, or even negative, due to inefficiencies in the allocation of public resources, high maintenance costs, and the low profitability of certain investments.

These theoretical controversies, contradictory empirical results, and observed realities in the Republic of Congo demonstrate that the question of the effects of road infrastructure investments on economic growth remains relevant and the debate is far from settled. Thus, the central question structuring this research is: what are the effects of road infrastructure investments on economic growth in the Republic of Congo? To answer this question, the objective of this study is to analyze the effects of road infrastructure investments on economic growth in the Republic of Congo. To this end, we support the hypothesis that road infrastructure investments have a positive effect on economic growth by improving the mobility of factors of production, reducing transport costs, and stimulating economic activity. The remainder of this work is organized as follows: the second section is devoted to the literature review; the third outlines the methodology; the fourth presents and discusses the empirical results; and finally, the fifth section concludes and formulates economic policy implications.

II. Literature Review

The issue of the effect of road infrastructure investments on economic growth has generated a wealth of theoretical and empirical literature. Indeed, some believe that public investments in road infrastructure positively influence economic growth. Others argue for a negative relationship between public investment in road infrastructure and economic growth.

From a theoretical perspective, most growth studies have begun their analytical framework with the neoclassical model. This model was developed by Ramsay (1928), Harrod (1939), Domar (1946), and Solow (1956). Solow (1956) attributes the origin of economic growth to the amount of technical capital invested (machinery, equipment, software, infrastructure, etc.). Thus, the Solow (1956) model, with its exogenous technological progress, predicts the convergence of economies. This is one of the limitations that encourages further research on economic growth and its explanation. This model is based on standard neoclassical assumptions. In other words, all savings are invested, returns are diminishing, and the perfect substitution of capital for labor is accepted. He departed from reality by assuming that per capita growth would gradually decline and eventually cease. Thus, in the absence of continuous technological innovation, per capita output growth stops. Observations have shown that economic growth, even at a slower pace, continues and remains a major feature of all developed economies.

The dynamics of Solow's model (1956) lie in explaining growth through the amount of technical capital. To better understand the problem of technological progress and its role in growth, Solow (1957) decomposes the economy's growth rate into contributions from factors of production (labor, capital) and a residual that is assumed to capture the externality of technological progress. It is in this sense that he concludes that technological progress constitutes the main driver of economic growth and considers it exogenous.

This contrasts with endogenous growth theories, which formalize models in which public capital has effects on long-term growth. According to endogenous growth theories, economic growth is considered a self-sustaining process driven by the accumulation of four factors: human capital, physical capital, technical capital, and public capital. These variables evolve according to an accumulation rate strongly linked to economic choices.

Indeed, new growth theories abandon the assumption of exogenous technological progress and instead posit endogenous growth, the primary cause of which is the accumulation of factors capable of generating economic growth. The existence of cumulative productive factors allows these theories to address externality phenomena overlooked by older theories. These new growth theories are based on the idea that returns to scale are not diminishing.

Undoubtedly, the foundational model of endogenous growth theories is that proposed by Romer (1986). Romer links growth to the accumulation of knowledge and technical skills. Investment is central to the dynamics of growth, as it enables the acquisition of new production techniques, increases productivity, and generates positive externalities that benefit other firms.

The second model developed by Lucas (1988) is based on the concept of human capital, which generates positive externalities that prevent the decline of factors of production, thus leading the economy towards self-sustaining growth. Romer's model (1990), developed following this work, considers that technological progress stems from research and development activity supported by economic actors. Finally, Barro (1990) analyzes the link between economic growth and public capital. Barro's theoretical work (1990) has seen a significant resurgence of interest and now constitutes a reference framework. To shed light on the contribution of productive spending on road infrastructure to growth, Barro (1990) considered a two-part model

incorporating infrastructure, approximated by public investment in road infrastructure. The first version of the model considers infrastructure as a pure, non-rivalrous, and non-excludable public good. From this perspective, firms benefit from the full amount of public investment in each period. The production function exhibits constant returns to scale across both accumulable factors (private and public capital), allowing for unbounded growth. However, it remains subject to diminishing returns to scale for firms, as each interprets public spending as external and cost-free. Thus, he deduces that road infrastructure is the source of the economy's unbounded growth. In the subsequent version of Barro's model (1990), infrastructure remains non-excludable but is now rivalrous. This situation describes the congestion phenomena so prevalent in developing countries. In this version, each producer generates a negative externality through their activity, as the increase in aggregate production reduces the amount of road infrastructure available per producer.

Regarding the empirical review, several studies are grouped according to two perspectives. The first group comprises studies that found a positive effect. The second group consists of studies that concluded with negative effects. Historically, Ratner (1983) was the first to estimate an expanded production function for the United States using time series data. Over the period studied (1949-1973), he found a public capital elasticity of 5.6%, for a production function constrained by constant returns to scale, with a time trend of 1.9%. By extending the observation period by 12 years and adding an oil price variable, Ram and Ramsey (1989) obtained a higher elasticity of 24% with a lower residual technological progress of 1.2%. A decomposition of public capital also allowed them to show that the contribution of locally owned infrastructure far exceeded that of federal investment (5%).

It is, however, following Aschauer's work that the debate on the productive impact of infrastructure intensified. Aschauer (1989) published two empirical studies on national productivity in the USA. Through estimations of the parameters of the Cobb-Douglas production function over the period 1945-1985, the author was able to show that: infrastructure has a positive effect on total factor productivity; the slowdown in productivity during the 1970s and 1980s could be due to a decrease in public investment in infrastructure; the estimated elasticity of total factor productivity with respect to infrastructure varied from 0.36% (1949-1967) to 0.49% (1968-1985). Subsequently, Munnell (1990) extended Aschauer's work using American data from 1949 to 1987 with a Cobb-Douglas aggregate production function. He demonstrated the positive relationship between labor productivity and the stock of public capital, in that a 1% increase in public capital changes labor productivity by between 0.31% and 0.39%. These results confirmed the direction of Aschauer's work concerning the American economy.

To concur with the findings of earlier work, Barro (1990) emphasized that public capital, in terms of physical infrastructure, stimulates the productivity of private agents and economic activity. Working with 98 countries over the period 1980-1985, Barro (1990) found a positive but statistically insignificant impact of public investment on economic growth. Following these pioneering studies, this topic truly attracted the attention of many researchers. This is the case with Etsiba (2018), who conducted an empirical analysis highlighting the link between investments in economic infrastructure and economic growth in Congo, notably using the OLS method based on error correction models (ECM). Their results show that public investments in economic infrastructure positively affect the pace of economic growth in Congo.

Continuing the empirical work of Aschauer (1989), Herrera (1996) examines the relationship between public investment and private productivity for 28 countries across Africa, Asia, and the Americas, using panel data from 1981 to 1991. The technique employed is ordinary least squares for an aggregate production function. The elasticity obtained is 0.20%, meaning that a 1% increase in the public capital stock implies a 0.20% increase in GDP.

Similarly, Laoyza and Odawara (2010) also conducted a study on the leverage effect that infrastructure improvements can have on the economic growth rate in Egypt compared to other countries. The estimation methodology consisted of modelling panel data and the results suggest that Egypt has reached a level of infrastructural performance consistent with its economic growth.

To explore the effect of transport infrastructure on economic growth and poverty reduction, Zou et al. (2008) used Chinese panel data and time series. Their findings indicate that the higher growth rate in eastern Central China is attributable to improved transport infrastructure. Using Granger causality testing, they found that investment in transport, particularly roads, is a driver of growth.

Fadonougbo and Koba (2008) analyzed the effects of infrastructure on economic growth in Benin, demonstrating that a 1% increase in transport investment boosts domestic output by 0.33%. Similarly, Pereira and Andraz (2005) show that transport infrastructure influences regional development trajectories, with better-endowed regions experiencing a concentration of productive activities.

In the case of Algeria, Ahmed Zakane (2009) highlights the impact of infrastructure spending on growth using vector autoregressive (VAR) models. He concludes, after several steps, that infrastructure spending influences economic growth by 13%. Ntita et al. (2017) studied the relationship between public investment and economic growth in the Democratic Republic of Congo (DRC) from 1981 to 2015. They used a

threshold effect model. The results of their econometric tests indicate an optimal public investment threshold of 22% of GDP, above which public investment has a positive and significant effect on the DRC's economic growth.

Similarly, Oulmakki (2017) studied the impact of transport infrastructure on economic growth in Morocco from 1980 to 2008 using a vector error correction model. He concludes that there is a positive link between highway infrastructure and economic growth.

Finally, among all the studies that have further demonstrated this positive link, there is also the one conducted by the National Institute of Statistics (INS) Niger (2020), which assesses the impact of public infrastructure projects on Niger's growth over the period from 1980 to 2017. The method used is principal component analysis (PCA) through an autoregressive model with staggered lags. The results obtained show that a 10% increase in the infrastructure stock leads to a 2.47% increase in long-term economic growth. In the short term, this impact is also positive but not statistically significant.

However, the second group mainly comprised studies highlighting the negative relationship. For example, Nadiri and Mamuneas (1996) estimated the effect of road capital on productivity growth at both the aggregate economy and industry levels. The estimation results show that the magnitude of the cost elasticity of road capital varies across industries. Negative elasticities (ranging from -0.746 to -0.220) in manufacturing industries led to the conclusion that road investments have negative effects on service industries in general. Furthermore, Waters (1999) studied the effect of road capital on the overall economy of the 10 Canadian provinces from 1961 to 1994 and on the goods-producing sector using a Cobb-Douglas and translog function. The results obtained show that there is generally no significant link between road capital and output, either in the economy as a whole or in the goods-producing sector. Often, the signs are even negative.

In their work, Shirley and Winston (2004) empirically found that spending on road infrastructure is negatively related to firms' inventory levels. The authors thus confirm that better transport infrastructure (the road network) allows firms to reduce the size of their inventories and, consequently, their storage costs. From a panelist perspective, Devarajean et al. (2001) locate the problem in the insufficient productivity of investment. These authors emphasize the low utilization of capacity and the lack of skills. Furthermore, their analysis of 29 African countries shows that, with the exception of Lesotho and Botswana, neither public nor private investment is correlated with economic growth. They conclude by saying that it is illusory to want to stimulate economic growth with an increased volume of investment without seeking to identify the factors behind the low return on investment.

Finally, Keho and Echui (2011) examined the relationship between investment in transport infrastructure and output in Côte d'Ivoire over the period 1970–2002. The results of Granger causality tests revealed that public investment in transport has no causal impact on economic growth, while conversely, economic growth has a causal impact on investment in transport.

In light of the preceding theoretical literature, it is important to note that the various theories employed are based on the idea that public investment in road infrastructure is a factor likely to influence economic growth. Thus, public investment in road infrastructure can have positive or limited effects on economic growth, both theoretically and empirically. This finding is particularly important given that the impact of public investment in road infrastructure on economic growth varies according to the country, region, time period, and methodological approach used.

III. Methodology

The objective of this paper is to analyze the effects of public investment in road infrastructure on economic growth. To this end, we draw inspiration from endogenous growth models with externalities, which rely on three-factor Cobb-Douglas production functions. Two factors are private (capital and labor), and the third is infrastructure, which is publicly funded. The model we propose to use is based on an unconstrained Cobb-Douglas functional form and is as follows:

$$\mathbf{Y_t = AK_t^{\beta} L_t^{\gamma} G_t^{\delta}} \qquad (\mathbf{1})$$

Where, t: time in year t; Y: economic growth measured by GDP; A: positive constant representing the technological parameter; K: private investment; L: labor measured by the active population; G: public investment in road infrastructure.

The mathematical translation of this relationship is as follows:

$$\mathbf{(LPIB)_t = \alpha_0 + \alpha_1 (LINVFR)_t + \alpha_2 (LINVP)_t + \alpha_3 (LOUV)_t + \alpha_4 (LPA)_t + \varepsilon_t} \qquad (\mathbf{2})$$

Where α_0, α_1, α_2, α_3 and $\boldsymbol{\alpha_4}$ are parameters to be estimated; t denotes time.

Data Source and Variables Used

The data used in this study were extracted from the World Bank database and the relevant sectoral ministry, and the study period spans from 1985 to 2023. This range is dictated by data availability.

Regarding the variables, the endogenous variable used in this study is GDP. It represents our dependent variable. This economic indicator measures the domestic economic output of a country. Its purpose is to quantify the wealth generated by a country over a given period, generally a quarter or a year, by economic agents residing within the country. It was used by Etsiba (2018). Based on the author's findings, we expect GDP to be positively affected by road infrastructure. This variable corresponds to private investment and serves as a control variable in this study. It was also considered in the work of Ghura, Dhaneshwar, and Hadjimichael (1996). Based on their study, we expect private investment to have a positive effect on economic growth in Congo. Public investment in road infrastructure represents our variable of interest. It encompasses public investments made in transport infrastructure, particularly roads. It was the subject of a study conducted in the case of WAEMU countries by Kane (2011), where the author used these different components in a disaggregated manner. Similar to his work, we expect road infrastructure to be significant and positively correlated with GDP. The trade openness of the economy, measured by the ratio of exports plus imports to GDP (Rodriguez and Rodrik, 1999), is also a factor. The labor force refers to the available workforce that sells its labor to production structures. The amount of labor supplied in an economy is proportional to the labor force; the latter is assumed to have a positive influence on production due to diminishing marginal returns. The descriptive statistics are presented in Table 1 below.

Table 1: Descriptive Statistics

	LPIB	LINVFR	LINVP	LOUV	LPA	LTBSS
Mean	22.38246	8.589253	3.347338	0.805884	14.13006	3.947548
Median	22.25984	8.871491	3.237895	0.805976	14.13321	3.900962
Maximum	23.48435	11.53225	4.356721	1.775165	14.72607	4.198937
Minimum	21.29389	3.912023	2.712124	0.056111	13.49525	3.810995
Std. Dev.	0.812854	1.915904	0.432830	0.526302	0.354364	0.106635
Skewness	0.087450	0.645272	0.723423	0.121263	0.060066	0.765967
Kurtosis	1.294849	2.765248	2.738803	1.754432	1.918131	2.344857
Jarque-Bera	4.774461	2.795994	3.512579	2.616670	1.925416	4.511058
Probability	0.091884	0.247091	0.172684	0.270270	0.381857	0.104818
Sum	872.9161	334.9808	130.5462	31.42946	551.0722	153.9544
Sum Sq. Dev.	25.10783	139.4861	7.118995	10.52577	4.771813	0.432101
Observations	39	39	39	39	39	39

Source: authors based on Eviews

Table 6 shows that GDP, public investment in road infrastructure, private investment, trade openness, labor force, and gross secondary school enrollment rate have the following mean values, respectively: 22.38246; 8.589253; 3.347338; 0.805884; 14.13006; and 3.947548. Overall, the range between the minimum and maximum values is large, and the mean values are greater than the standard deviation. There is significant dispersion of all variables around their respective means. Furthermore, the probability associated with the Jarque-Bera statistic for all six variables is greater than 5%. This indicates that the null hypothesis (H0) is accepted at the 5% significance level.

Stationarity Tests

The existence of stationarity in variables is a fundamental condition for estimating a time series econometric model. By definition, a time series is said to be stationary when its mean and variance are constant over time and when the value of the covariance between two time periods depends only on the difference between these two periods and not on the time at which the covariance is calculated. To determine this, variables are examined using three tests: ADF, PP, and KPSS.

Table 2: Stationarity Test

	At level					In first difference			
Variables	Types of tests	Critical values at the 5% threshold	Stat-test	Probability	Conclusion	Critical values at the 5% threshold	Stat-test	Probability	Conclusion
LPIB	ADF	-3,533083	-2,0959	0,5315	X	-3,540328	-5,0892	0,0011	I(1)

			04				87		
	PP	-3,533083	-2,189767	0,4814	X	-1,950117	-5,411043	0,0000	I(1)
	KPSS	0,463000	0,686784	X	X	0,463000	0,106152	X	X
LINVR	ADF	-3,540328	-1,528037	0,8009	X	-3,540328	-5,135318	0,0010	I(1)
	PP	-2,941145	-2,004472	0,2838	X	-3,536601	-6,628566	0,0000	I(1)
	KPSS	0,146000	0,129865	X	X	0,463000	0,110802	X	X
LINVP	ADF	-3,533083	-2,229866	0,4603	X	-3,536601	-6,408780	0,0000	I(1)
	PP	-3,533083	-2,382122	0,3825	X	-3,536601	-7,051414	0,0000	I(1)
	KPSS	0,146000	0,104527	X	X	0,146000	0,102213	X	X
LOUV	ADF	-1,951000	-0,843391	0,3432	X	-3,536601	-6,200534	0,0000	I(1)
	PP	-1,949856	-0,997686	0,2800	X	-3,536601	-6,245410	0,0000	I(1)
	KPSS	0,433407	0,463000	X	X	0,146000	0,083123	X	X
LPA	ADF	-3,533083	-3,339071	0,0753	X	-3,536601	-6,722048	0,0000	I(1)
	PP	-2,941145	-1,177733	0,6740	X	-3,536601	-7,020238	0,0000	I(1)
	KPSS	0,463000	0,766771	X	X	0,146000	0,123235	X	X
LTBSS	ADF	-3,533083	-2,243542	0,4531	X	-2,243427	-5,984507	0,0000	I(1)
	PP	-3,533083	-2,309618	0,4189	X	-3,536601	-6,105744	0,0001	I(1)
	KPSS	0,463000	0,256272	X	X	0,146000	0,052226	X	X

Source: authors based on Eviews

The table above highlights the summary of stationarity test results obtained using EViews 9 with the ADF, PP, and KPSS stationarity tests, respectively. The results show that all variables are stationary in first difference (LPIB, LINVFR, LINVP, LOUV, LPA, LTBSS). Furthermore, no series is stationary in second difference, which is essential for applying the MCE model. Therefore, it is now necessary to perform cointegration tests to determine if at least one cointegrating relationship exists.

Study of the Cointegration of Series

The concept of cointegration provides a theoretical framework for studying equilibrium and disequilibrium situations that prevail in the long and short term, respectively. If variables are cointegrated, they admit a dynamic specification of the correct error type, which transforms the initial regression problem on non-stationary variables. Cointegration allows us to identify the true relationship between variables by searching for the existence of a cointegrating vector and eliminating its effect, if present.

However, it is common to want to work with level variables rather than first-difference variables. To ensure that the regression performed on level variables is error-free, it is essential to first conduct a cointegration test. In this regard, we do not have spurious regressions when variables are cointegrated. The cointegration test is performed using two approaches: the Engle-Granger approach and the Johansen approach.

First approach: The Engle-Granger approach

To highlight potential cointegrating relationships, the simplest and oldest approach is that suggested by Engle Robert and Granger. The Engle-Granger cointegration test allows us to see if variables are integrated in the long run.

The method proposed by Engle Robert and Granger Clive implicitly assumes the uniqueness of the cointegrating vector. We then choose one of the system variables as the dependency and apply the OLS procedure to the static regression on the variables taken at levels.

Deterministic cointégration : $y_{1t} = \alpha + \beta y_{2t} + \varepsilon_t \qquad t = 1, \ldots\ldots n;$ (3)

Cointégration stochastique : $y_{1t} = \alpha + \delta_t + \beta y_{2t} + \varepsilon_t \quad t = 1, \ldots\ldots n;$ (4)

y_1 is a vector of dimension (n, 1), and y_2 is a vector consisting of m variables. For a cointegrating relationship to be accepted, the residual (ε_t) resulting from this previous regression must be stationary. Let's perform the ADF test under the following hypotheses:

H_0: unit root in the residuals (no cointegration);

H_1: no unit root in the residuals (cointegration).

Second approach: Johansen's test

It should be noted that the tool, now a standard in macroeconometrics for analyzing long-term relationships, is the very popular approach of Johansen and Juselius (1990). This approach relies on estimating, using the maximum likelihood method, under the assumption of independently and identically distributed errors like a normal distribution, the VECM associated with the vector of variables studied. Denoting this vector by X_t, the associated OLS will have the following general formulation:

$$\Delta X_t = \Sigma \Gamma_i \Delta X_{t-1} + \alpha\beta' X_{t-1} + \phi D_t + U_t \qquad \boldsymbol{i = 1, 2, 3 \ldots p} \qquad (\mathbf{5})$$

Where X_t is an (n, 1) vector, Γ_i an (n, n) vector representing the short-term dynamics, α and β' are of dimension (n, r), α represents the matrix of adjustment coefficients, β' the matrix of r cointegrating vectors, Dt an (n, 1) vector with deterministic components, and U_t is a B(0, Ω). It is used to verify the cointegration of series using a cointegration rank test. The hypothesis test is as follows:

H_0: No Cointegration (Cointegration rank is zero);

H_1: Cointegration (Cointegration rank greater than or equal to 1);

LR: Likelihood Ratio;

CV: Critical Value.

The Cointegration hypothesis is accepted if LR is greater than CV and rejected otherwise.

Figure 1: Johansen's test

Date: 04/20/25 Time: 22:20 Sample (adjusted): 1987 2023				
Included observations: 37 after adjustments				
Trend assumption: Linear deterministic trend				
Series: LPIB LINVFR LINVP LOUV LPA LTBSS				
Lags interval (in first differences): 1 to 1				
Unrestricted Cointegration Rank Test (Trace)				
Hypothesized		Trace	0.05	
No. of CE(s)	Eigenvalue	Statistic	Critical Value	Prob.**
None *	0.771007	122.5375	95.75366	0.0002
At most 1	0.559131	67.99708	69.81889	0.0692
At most 2	0.421829	37.69383	47.85613	0.3155
At most 3	0.318012	17.42204	29.79707	0.6088
At most 4	0.073835	3.260531	15.49471	0.9538
At most 5	0.011355	0.422529	3.841466	0.5157
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level				
* denotes rejection of the hypothesis at the 0.05 level				
**MacKinnon-Haug-Michelis (1999) p-values				

Source: authors based on Eviews

Error Correction Model (ECM)

The use of the error correction model reveals the common cointegration relationship (the common trend) and allows us to deduce the interactions between the variables (Régis, 2005).

There are two methods for estimating an error correction model. For optimality, we will perform the estimation in a single step (Hendry's method).

If we want to express Y as a function of X and Z using the ECM method, then we have:

$$\Delta Y_t = \alpha_0 + \alpha_1 \Delta X_t + \alpha_2 \Delta Z_t + \beta_0 Y_{t-1} + \beta_1 X_{t-1} + \beta_2 Z_{t-1} + \varepsilon_t \quad (6)$$

For the MCEs to be validated, the coefficient β0, called the error correction coefficient, must be significantly between -1 and 0.

Application of the error correction model

We estimated the error correction model whose mathematical formula is as follows:

$$\Delta \ln PIB_t = \alpha_0 + \alpha_1 \Delta(\ln INVFR_t) + \alpha_2 \Delta(\ln INVP_t) + \alpha_3 \Delta(\ln OUV_t) + \alpha_4 \Delta(\ln PA_t) + \beta_0(\ln PIB_{t-1}) + \beta_1(\ln INVFR_{t-1}) + \beta_2(\ln INVP_{t-1}) + \beta_3(\ln OUV_{t-1}) + \beta_4(\ln PA_{t-1}) + \varepsilon_t \quad (7)$$

Figure 2: One-step ECM estimation

Dependent Variable : D(LPIB)				
Method : Least Squares				
Date : 04/20/25 Time : 22:24				
Sample (adjusted) : 1986 2023				
Included observations : 38 after adjustments				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(LINVFR)	0.024280	0.015907	1.526297	0.1390
D(LINVP)	-0.082119	0.073551	-1.116490	0.2744
D(LOUV)	-0.629970	0.080209	-7.854085	0.0000
D(LPA)	3.310006	1.098394	3.013495	0.0057
D(LTBSS)	-0.232524	0.231734	-1.003407	0.3249
C	7.039076	1.904782	3.695477	0.0010
LPIB(-1)	-0.754135	0.172624	-4.368664	0.0002
LINVFR(-1)	0.052985	0.013848	3.826071	0.0007
LINVP(-1)	-0.007482	0.060082	-0.124527	0.9019
LOUV(-1)	-0.522522	0.152874	-3.417990	0.0021
LPA(-1)	0.850154	0.199164	4.268606	0.0002
LTBSS(-1)	-0.570857	0.243978	-2.339788	0.0272
R-squared	0.877202	Mean dependent var		0.051545
Adjusted R-squared	0.825250	S.D. dependent var		0.203471
S.E. of regression	0.085057	Akaike info criterion		1.838898
Sum squared resid	0.188103	Schwarz criterion		1.321765
Log likelihood	46.93905	Hannan-Quinn criter.		1.654906
F-statistic	16.88459	Durbin-Watson stat		2.137132
Prob(F-statistic)	0.000000			

Source: authors based on Eviews

The results from the error correction model (ECM) estimation show that public investments in road infrastructure have different effects on economic growth depending on the time horizon considered. The one-step model has a coefficient of determination (R^2) of 0.8772, meaning that the explanatory variables explain 87.72% of the dependent variable. Furthermore, since the model's probability is less than 5% (F-statistic = 0.000000), we can say that the model is globally significant. Moreover, we also note that the recall strength is significant and has the expected sign (-0.754135). Thus, we can validate the application of an ECM. The Durbin-Watson statistic (2.137), close to 2, also indicates the absence of autocorrelation of the errors, which confirms the robustness of the estimates.

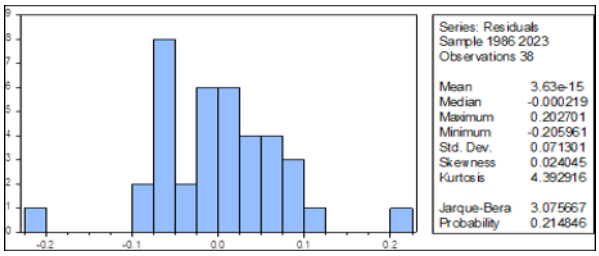
Before interpreting the model results, we will first verify whether the assumptions made about the model are valid. These include, among others, model validation tests (stationarity, non-autocorrelation, normality of residuals, and White's Heteroskedasticity test), a model stability test.

Model Validation Test

The results in Figure A2 in the appendix indicate that the model residuals are stationary.

Similarly, based on the results in Figure A3, the p-value (0.47) of the Jarque-Bera normality test of the residuals is well above 5%, and all the terms of the autocorrelation functions (simple and partial) are not

significantly different from zero. They are all located within the confidence interval represented by the vertical lines on the graph.



Source: authors based on Eviews

To test for the absence of autocorrelation in the residuals, the most commonly used test is the Breusch-Godfrey test shown in Figure A5. This test is based on Fisher's F-statistic or the Lagrange Multiplier (LM-Test), whose test statistic is R^2.

The general idea of the test is to look for a significant relationship between the residual and the same lagged residual. The results of the Breusch-Godfrey test for p=2 are presented. Upon reviewing these results, we observe that all probabilities are greater than 5%.

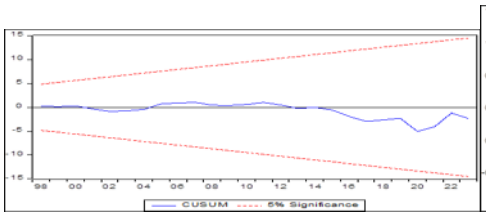
Breusch-Godfrey Serial Correlation LM Test:				Heteroskedasticity Test: White			
F-statistic	2.221563	Prob. F(2,24)	0.1303	F-statistic	2.192540	Prob. F(20,17)	0.0536
Obs*R-squared	5.936015	Prob. Chi-Square(2)	0.0514	Obs*R-squared	27.38387	Prob. Chi-Square(20)	0.1248
				Scaled explained SS	27.33548	Prob. Chi-Square(20)	0.1261

Source: authors based on Eviews

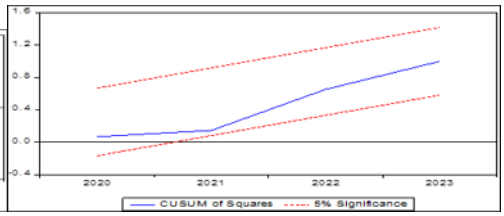
Stability Test of the Coefficients

We now want to ensure the overall stability of the model parameters. To this end, we perform the CUSUM and CUSUM-SQUARE tests on Figures A5 and A6. These tests allow us to detect structural and point instabilities.

Reading Figures A6 and A7 reveals that the model is structurally and pointwise stable because the curves do not intersect the corridors.



Source: authors based on Eviews



Source: authors based on Eviews

Interpretation of Results

The various results obtained show that public investments in road infrastructure significantly impact economic growth in both the short and long term. Based on the model results, exogenous variables explain 87.72% (R^2) of the endogenous variable.

An examination of the relevance of the long-term dynamics shows that public investments in road infrastructure have a positive and statistically significant effect on economic growth in the Republic of Congo. The estimated coefficient of 0.052985 indicates that a 1% increase in public investments in road infrastructure leads, all other things being equal, to an increase of approximately 0.053% in the gross domestic product (GDP) in the long term. Although this elasticity is relatively low, it reflects the existence of a lasting effect of road infrastructure on economic activity. This result corroborates the theoretical principles of endogenous growth, notably developed by Barro (1990), according to which public infrastructure constitutes productive capital that generates positive externalities. By improving the accessibility of production areas, reducing transportation costs, facilitating trade and the mobility of factors of production, road infrastructure strengthens business productivity and stimulates private investment. It also contributes to greater market integration, reduced spatial disparities, and increased economic competitiveness.

These results are consistent with those obtained by Aschauer (1989), Batana (1997), Véganzonès (2000), and Etsiba (2018), who highlight a positive contribution of public infrastructure investment to economic growth. Conversely, they contradict the findings of Waters (1999) and Khanam (1999), who found no

significant effect of road infrastructure on growth in the Canadian context. This divergence can be explained by differences in the level of economic development, infrastructure quality, public governance, and the estimation methods used.

In the specific context of the Republic of Congo, several factors explain this long-term positive relationship. Since the early 2000s, substantial oil revenues have enabled the government to finance several public investment programs, including Accelerated Municipalization, the Poverty Reduction Strategy Paper (PRSP), the National Development Plan (NDP), and various projects to improve the national road network. These investments have opened up access to many isolated areas, improved the movement of people and goods, reduced logistical costs, and facilitated access for agricultural producers to urban markets. They have also strengthened trade between the country's main economic hubs, including Brazzaville, Pointe-Noire, Ouesso, Owando, and Dolisie, thus contributing to greater economic integration across the country.

In contrast, in the short term, public investments in road infrastructure have a positive but statistically insignificant effect on economic growth, as indicated by the coefficient of 0.024280 associated with a probability of 0.1390, which is higher than the conventional threshold of 5%. This result suggests that the economic effects of road investments do not materialize immediately after their implementation.

This lack of short-term significance stems from the very nature of road infrastructure projects. Their implementation generally requires several years of planning, financing, and construction before the economic benefits can be fully realized. During the implementation phase, a large portion of the expenditure is absorbed by the costs of studies, material acquisition, equipment mobilization, and payments to public works companies, without these investments immediately translating into a significant increase in national output. Furthermore, implementation delays, cost overruns, institutional constraints, difficulties in maintaining the road network, and governance deficiencies observed in some public projects in Congo can further delay the expected effects on growth. This finding is confirmed by the work of Gasser and Navarre (1991), who emphasize that infrastructure projects generally produce their economic effects after a certain period, once the works are completed and effectively used by economic actors. It also supports the findings of Etsiba (2018), which highlights, in the case of Congo, a lack of significant effect of public investments in economic infrastructure on short-term growth, while the effects become positive and significant in the long term.

IV. Conclusion And Economic Policy Implications

The main objective of this study was to analyze the effect of public investments in road infrastructure on economic growth in the Congo during the period from 1985 to 2023. To achieve this, we used an error correction model employed by Etsiba (2018) based on data from the World Bank and the relevant sectoral ministries. The results obtained after estimating our econometric model show that public investments in road infrastructure have a positive influence on economic growth in the Congo (in both the short and long term), which is consistent with the results obtained in 2018 by Etsiba, using the same model as that adopted in our study.

These results can be explained, on the one hand, by the development of income-generating activities resulting from the implementation of socio-economic development programs (PND, DSRP, Accelerated Municipalization, etc.) initiated by the government since the early 2000s. On the other hand, the construction of this infrastructure has a multiplier effect through the construction sector on the entire economy.

The results we have obtained throughout this work imply a number of economic policy implications. To this end, in order to improve economic growth and achieve healthy and sustainable growth, public authorities should develop relevant strategies that address the current challenges related to road infrastructure, because the path to development lies in road development. Thus, we formulate the following economic implications:

- Increase investment in the transport sector, particularly road transport, as this generates productivity gains and is a necessary condition for industrialization;
- It is imperative to strengthen the maintenance services for acquired road infrastructure. To do this, it is necessary for the competent authorities to consider public-private partnership mechanisms in this sector.

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