Revisited the Relationship Between Economic Growth and Transport Infrastructure in India: An Empirical Study

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Abstract

This study empirically re-examines the relationship between transport infrastructure and economic growth in India for the period 1990–2017. Multivariate dynamic models are applied to estimate the relationship between economic growth and different modes of transport infrastructure namely road, rail and air transports in the vector error correction model framework. The results reveal that road and air transports have significant positive contribution to economic growth in the long-run while rail transport is insignificant. This study further examines the said issue using unit free index variables and has constructed a composite index of transport infrastructure using principal component analysis to analyze the nexus between aggregate transport infrastructure and economic growth in India in the post globalization era. The results of the study indicate the bidirectional causality between aggregate transport infrastructure and economic growth. Results of this study suggest incorporating feedback issue in policy formulations.

Key words: Multivariate model, Composite Index, Transport Infrastructure, Globalization, VECM, PCA, Causality.

JEL Classification Number: C22, O18, R4

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I. Introduction

The economists and policy makers recognize transport infrastructure as a crucial factor for sustainable economic growth. Many studies[1] show that integrated and well-functioning transport facilities are necessary for achieving sustainable economic growth. Recently, according to the World Bank, India emerges as the fastest growing economy in the World[2]. One of the possible reasons behind this success might be the outcome of several factors particularly, massive investment in infrastructure which was initiated in road infrastructure[3] in India since early in the 21st century. In this context, the relevant question arises whether transport infrastructure is the cause of economic growth in the post globalization era in India. The present study revisits the ongoing debate over this issue in the context of India.

Demand for Infrastructure especially, transport infrastructure for economic growth is age old. Various economic theories have been put forwarded to justify the role of transport infrastructure in a country's economic progress. Amongst them some supported the view that enlarged availability of transport facilities are the essential pre-condition for economic development[4]. However, Wagner (1958) opposed the view of Hirschman (1958) and argued that demand for transport facilities would grow if and only if development takes place. So, there is a debate over the causal relationship between transport infrastructure and economic growth. In other words, whether transport infrastructure causes economic growth or economic growth itself is the cause of demand for transport infrastructure. Empirical literature provides controversial role of transport infrastructure in the process of economic growth. Aschauer (1990), Khadaroo and Seetanah

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[1] See Shah, 1992; Sanchez and Robles, 1998; Short and Kopp, 2005; Tripathi and Goutam, 2011; Pradhan and Bagchi, 2012 etc.

[2] See the article "India's growth rate set to surpass China this year: World Bank" in *The Economic Times* (2015, June 11); and also see remarks of KausikBasu, the Chief Economist of the World Bank (see Dinda 2016).

[3] The Golden Quadrilateral Highway project was launched in India in 1999 by Atal Bihari Vajpayee, Prime Minister of India and it gains momentum and visible since 2002-2003.

[4]See, Hirschman (1958), Wagner (1958), Barro (1990), Barro and Sala-I-Martin (1992, 1995), etc

(2008), Tripathi and Goutam (2011), Pradhan and Bagchi (2013), and Mohmand et al. (2016) supported the view that the availability of well-developed transport facilities is the cause of economic growth. Opposing the above said view, Gramlich (1994), Ramanathan and Parikh (1999), Maparu and Mazumder (2017) suggested that economic growth causes transport sector to grow further. Thus, the outcomes of the empirical studies[5] are inconclusive and still unsettled.

In the context of India, few studies have been conducted to estimate the nexus between transport infrastructure and economic growth (Tripathi and Goutam, 2011; Sahoo and Dash, 2011; Pradhan and Bagchi, 2013; Ghani et al. 2014; Maparu and Mazumder, 2017). Overall, the results of these studies revealed that transport infrastructure plays a crucial role in economic growth. In most of the cases either road transport or both road and rail transports have considered as proxy for transport infrastructure. However, the multidimensional facet of transport infrastructure will not be reflected adequately if we consider transport infrastructure as one-dimensional phenomenon i.e. use them separately in a bivariate framework. This is because the use of bivariate model may mislead to the biased causality inferences due to the omission of relevant variables (Lutkepohi, 1982). Present study attempts to provide a better estimation technique by taking different sub-sectors of transport infrastructure as explanatory variables to estimate the nexus between transport infrastructure and economic growth unlike previous studies that have taken only one sub-sectors of transport infrastructure as explanatory variable under ceteris paribus assumption. The use of different sub-sectors of transport infrastructure in a multivariate structure[6] helps us to capture the multidimensional aspects of transport infrastructure. However, this may create problems like

[5]See, Stephan (2000), Khadaroo and Seetanah (2008), Nwakwze and Mulikat (2010), Bosede et al. (2013), Tong et al. (2014), and Wessel (2019).

[6] The regression coefficient in a multivariate structure measures the partial out effect of each independent variable on the dependent variable (Das, 2019, pp. 138)

multicollinearity if all the indicator variables are highly correlated to each. Therefore, present study develops a composite time series index of transport infrastructure using principal component analysis (PCA)[7] to avoid such problem and revisits the relationship between transport infrastructure and economic growth in India in the post globalization period.

The rest of the paper is organized as follows: Section II summarizes the existing literature. Section III presents a brief overview of transport infrastructure development in the post globalization period in India. Section IV describes the sources of data and econometric methodologies used in the study. Section V analyses the empirical results. Finally, conclusions and policy suggestions are presented in Section VI.

II. Review of Literature:

The nexus between transport infrastructure and economic growth had been started with Antle (1983) when he measured the effects of transportation and communication infrastructure on aggregate agriculture productivity using a Cobb-Douglas production function for 47 LDCs (Less Developing Countries) and 19 DCs (Developed Countries). He found a strong and positive association between the level of infrastructure and aggregate agriculture productivity. This finding is in line with Aschauer (1989), who found that the elasticity of GDP with respect to core (such as street lights, highways, airports, mass transit services, sewerage, and electricity and gas) infrastructure was 0.24 and concluded that in the U.S core infrastructure contributed more to productivity than other forms of infrastructure. Eberts (1990), Munnell (1990), Garcia-Mila and McGuire (1992) etc. have also found a high output elasticity of some public capital infrastructure. The positive contribution of transport infrastructure has also been addressed by Fernald (1999)

[7] PCA transforms a set of highly correlated regressors into a set of uncorrelated artificial variables expressed as some linear combination of the original regressors (Das, 2019, pp. 148).

where he reported that output elasticity of highway capital in U.S economy for the period 1953 to 1989 was 0.35. He concluded that industries who used road transport intensively, have a faster growth of factor productivity than others. Stephan (2000) measured the effects of public infrastructure (consisting transport and human capital infrastructure) to local private production using a panel data set of 327 German counties and found that transport and human capital positively contribute to the productivity and output of local private sector. Fan and Zhang (2004) used 1996 Agricultural Census dataset of China and estimated the effects of rural infrastructure (road density) on both farm and nonfarm production. Using a simultaneous equation system, they concluded that the role of rural infrastructure and education are much higher to the productivity of nonfarm sector than agriculture productivity. Khadaroo and Seetanah (2008) examined the association between transport capital and economic growth for Mauritius over the period 1950-2000 using a dynamic time series analysis in a vector error correction model (VECM) framework and found a positive contribution of transport infrastructure to the economic performance of Mauritius. Tripathi and Goutam (2010) examined the long-run equilibrium relationship between road transport, employment, output and gross capital formation in India from1970-71 to 2007-08. They used vector auto-regression approach (VAR) to analyze the impact of road transport on such macroeconomic variables. The results of their study revealed that road transportation has a significant and positive long-run relationship with economic growth and gross public capital formation. This result is in line with Pradhan and Bagchi (2013), who have also showed a positive contribution of transport infrastructure (consisting road and rail) to economic growth in India during 1970-2010. Using vector error correction model (VECM) they found bidirectional causality between road infrastructure and economic growth and road infrastructure and gross domestic capital formation, unidirectional causality from railway infrastructure to economic growth, and gross domestic capital formation, and finally, unidirectional causality from total transport to economic growth and gross capital formation in India. Similar results have been found by Mohamand et al. (2016). They have measured the impact of transportation infrastructure on economic growth in Pakistan using a panel data of developed and less developed provinces. The results of their study found bidirectional causality between transport infrastructure and economic growth in case of rich and much developed provinces and unidirectional causality from economic growth to transportation infrastructure in underdeveloped provinces. Maparu and Mazumder (2017) examined the causal relationships between transport infrastructure (road, rail, air, and port infrastructure), economic development and urbanization in India from the period 1990-2011. They used several time series estimation techniques such as, Engle and Granger cointegration test, Johansen cointegration test, vector error correction model (VECM), and Granger causality test to conduct the analysis of their study. Their results showed that in the long-run, transport infrastructure is cointegrated with economic development, and the directional of causality is from economic development to different sub-sectors of transport infrastructure in most of the cases and drawing support in favour Wagner's law. However, no causation has been found from urbanization to transport infrastructure but the reverse is not true as unidirectional causation runs from highway and port transport to urbanization. Wessel (2019) analyzed the effects of specific mode of transport infrastructure on trade using a gravity equation model with European trade flows. The results of the study showed that improvement of certain types of transport infrastructure have difference trade effects among them rail and air infrastructure are more responsive to quality improvements in the corresponding infrastructure while road density rather than road quality has a positive trade effect.

III. State of Indian Transport Infrastructure in the Post Globalization Period

This section comprises the state of different sub-sectors of transport infrastructure along with their contributions to GDP in India. Table 1 represents the state of different modes of road transport in India over the last three decades. The table shows that share of national highways has increased from1.67% in 1990-91 to 2.15% in 2015-16. The share of state highways on the other hand has decreased from 6.31% in 1990-91 to 3.75% in 2015-16. The share of PWD roads, rural roads, and urban roads has also increased during 1990-91 to 2015-16.

Table 1: Category wise Share of Road to Total Road Length

Year	National highways	State highways	Other Public Works Department (PWD) Roads	Rural roads	Urban roads	Project roads
1990-91	1.67	6.31	25.26	47.09	9.26	10.40
2000-01	2.33	5.34	29.76	43.34	10.19	9.04
2010-11	1.87	4.32	26.52	48.80	10.87	7.61
2015-16	2.15	3.75	NA	64.54	10.84	6.78

Table 2 represents the state of railway transport infrastructure in India over the last three decades. It shows that double line railway track has increased from 22.98% in 1990-91 to 31.85% in 2015-16 while single line railway track has decreased from 77.02% in 1990-91 to 68.15% in 2015-16. Total number of railway stations and railway bridges has also increased from 1990-91 to 2015-16. Total number of level crossing has decreased from 1990-91 to 2015-16.

Table 2: State of Railway Transport in India

Year	Single line (% share of total railway line)	Double/ multiple line (% share of total railway line)	No. of Stations	No. of Bridges	Level crossings
1990-91	77.02	22.98	7100	116000	37117
2000-01	74.60	25.40	6843	119984	38561
2010-11	70.18	29.82	7133	133160	32735
2015-16	68.15	31.85	7216	140919	28607

Table 3 represents the state of airport traffic statistics in India in the period of post economic reforms. During 1995-96 to 2017-18, domestic aircraft movements have increased from 3.15 to 18.87 lakhs. Total number of domestic passengers has also increased from 255.6 lakhs in 1995-96 to 2432.78 lakhs in 2017-18. Total number of domestic cargos handled has also increased from 2.126 lakhs tonnes in 1995-96 to 12.13 lakhs tonnes in 2017-18.

Table 3: Airport Traffic Statistics in India

Year	Domestic Aircraft Movements (lakh)	Number of Domestic Passenger (lakh)	Domestic Cargo Handled (lakh tonnes)
1995-96	3.147	255.64	2.126
2000-01	3.866	280.176	2.884
2010-11	10.936	1055.227	8.527
2017-18	18.866	2432.779	12.131

Table 4 provides the composition of various sub-sectors of the transport sector in terms of GDP. Table 1.D shows the contribution of transport sector in India's GDP for the period of 1999-00 to 2010-11. The share of transport sector in India's GDP has increased from 6.0% in 1999-00 to 6.5% in 2010-11. In particular, the share of road transport infrastructure in GDP has increased while that of railways have fallen during 1999-00 to 2010-11. Table 4 suggests that road transport is the most dominant segment in India's transport sector with a share of 6.5% in GDP in 2010-11 in comparison to 1.0% GDP share of railways in the same year. . However, the share of air and water transport infrastructures in GDP have remained either constant or grown marginally during this period. Therefore, the entire increase in percentage share of transport sector in GDP since 1999-00 has come from road transport sector only.

Table 4: Share of GDP of Different Transport Modes in India during 1999-00 to 2010-11

Year	Transport	Road	Rail	Air	Water
1999-00	6.0	3.8	1.3	0.2	0.2
2000-01	6.0	3.9	1.3	0.2	0.2

2001-02	6.0	3.9	1.2	0.2	0.2
2002-03	6.2	4.1	1.2	0.2	0.2
2003-04	6.3	4.3	1.2	0.2	0.2
2004-05	6.7	4.8	1.0	0.2	0.2
2005-06	6.7	4.8	1.0	0.2	0.2
2006-07	6.7	4.8	1.0	0.2	0.2
2007-08	6.7	4.7	1.0	0.2	0.2
2008-09	6.6	4.8	1.0	0.2	0.2
2009-10	6.5	4.7	1.0	0.2	0.2
2010-11	6.5	4.7	1.0	0.3	0.2

Notes: Data up to 2003-04 are at 1999-2000 prices. Data from 2004-05 onwards are at 2004- 05 prices. All shares in GDP are inclusive of Financial Intermediation Services Indirectly Measured.
Source: Central Statistical Organization.

IV. Data and Methodology

For conducting the analysis, this study takes three components of transport infrastructure namely, road density (total road length per 1,000 sq km), railway density (total railway route length per 1,000 sq km) and air density (domestic aircraft flown per 1,000 sq km), and GDP per-capita (constant 2011-12 in Rupees) as a proxy for economic growth in India for the period 1990-2017. All the indicators of transport infrastructure are taken from the Economic outlook of India - the CMIE database while GDP per-capita is obtained from the hand book of statistics, Reserve Bank of India (RBI). All the variables are used in real terms, and then transformed to natural logarithms i.e. road density as lnRODN, rail density as lnRLDN, air density as lnARDN, and economic growth as lnGDPPC.

The present study applies Vector Error Correction Model (VECM) to assess the long run equilibrium relationship between road, rail, and air transports and economic growth as well as their short run dynamics. Since, the use of the VECM (see equation 1a in Appendix) requires the series to be cointegrated with the integration of order one i.e. *I* (1), therefore, Engle-Granger cointegration (1987) test and Johansen Co-integration (1988) test are applied to check the cointegrating nature of the variables. Engle and Granger test of cointegration method applies ADF test on the residuals (see equation 1b in Appendix) estimated from the cointegrating regression between the variables. On the other hand, Johansen test of Co-integration (1988) proposes two different likelihood ratio tests namely; the Trace test (see equation 1c in Appendix) and Maximum Eigen value test (see equation 1d in Appendix) to analyze the long-run associations among the variables.

V. Results and Discussion

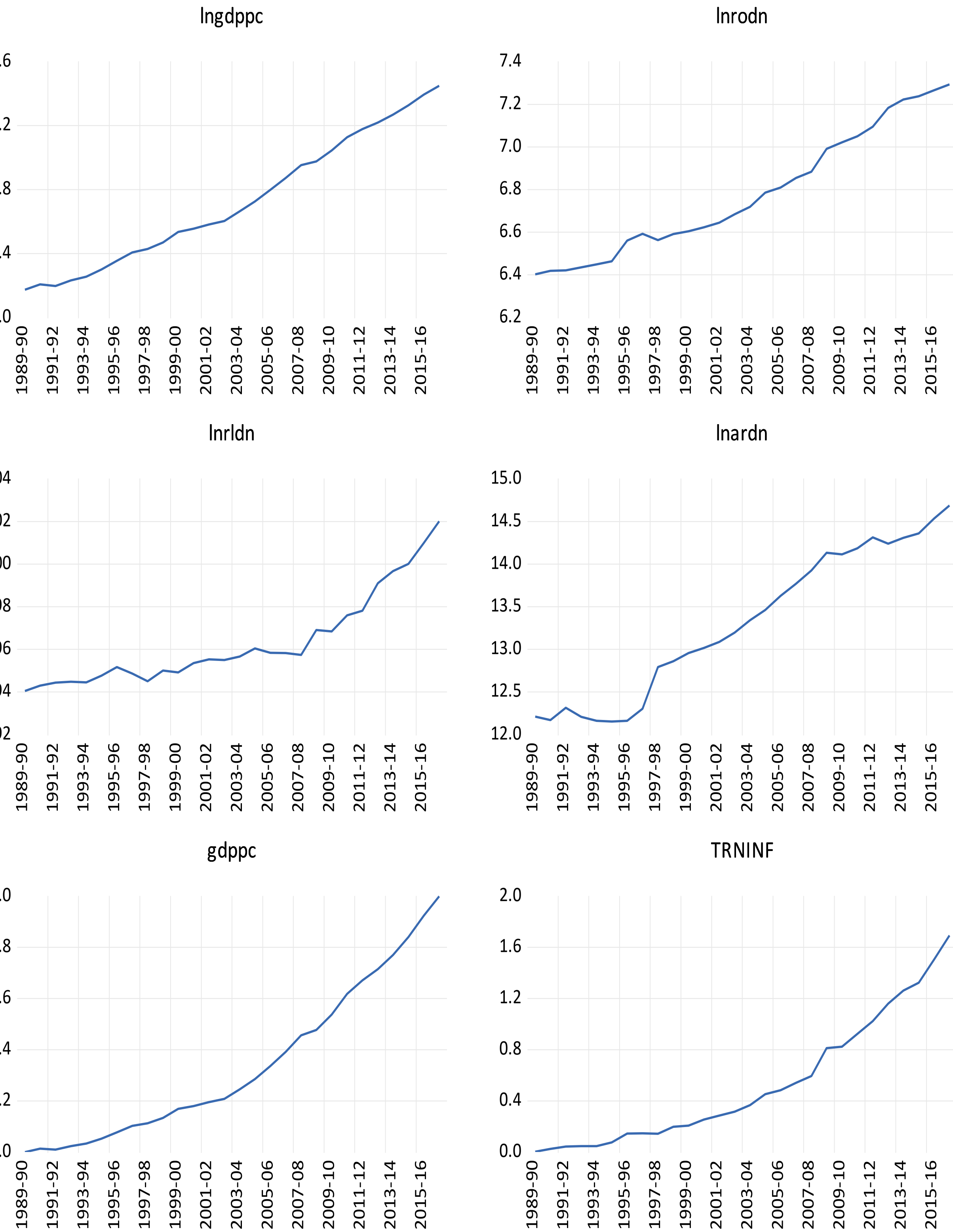
a. Basic Results

The underlying assumption of time series empirical work is based on stationary data that might avoid spurious regression[8]. Therefore, it is necessary to check the nature of the data generating process (DGP)[9] of a time series variable i.e., whether this process is stationary or not before using it in time series estimation. A data generating process is said to be stationary (weekly) if its mean and variance are time-invariant and its covariance depends on time difference only. We use two different ways to detect the stationary nature of a time series viz. visual inspection of the data plots (Figure 1 and Figure 2) and numerical judgement with unit root tests (see Table 5). Figure 1 displays lnGDPPC, lnRODN, lnRLDN, lnARDN, income index (GDPPC) and index of transport infrastructure (TRNINF) for the period of 1989-90 to 2016-17. All the series show a tendency to drift upwards over time (See Figure 1) at their levels and therefore, they are non-stationary in mean. Otherwise, they are stationary in mean at their first difference (See Figure 2).

[8] Spurious regression arises when two variables are independent of each other but has time trends or it's a regression between two non-stationary time series.

[9] The process of realization of a time series data is known as data generating process (DGP) (Das, 2019, pp. 248)

Figure 1: Time series behaviour of all the variables at level



Source: Authors' calculation

Figure 2: Time series behaviour of first difference of all the variables

Source: Authors' calculation

The Augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1981) and Phillips Perron (PP) test (Phillips-Perron, 1988) are performed to examine the stationary properties of the variables and their order of integration. We use both ADF and PP tests mainly because of their methodological differences. In ADF test, the serial correlation and heteroscedasticity in the errors are corrected parametrically by incorporating augmented terms in the model whereas, the PP test non-parametrically corrects serial correlation and heteroscedasticity in the residuals of error terms by modifying the ADF test statistics (Das, 2019, pp. 326-27). Results of ADF and PP tests are reported in Table 5. The results of Table 5 show that lnGDPPC, lnRODN, lnRLDN, lnARDN, normalized GDPPC and index of TRNINF are non stationary at level as the null hypothesis of unit roots for both the test cannot be rejected for all the variables. However, first differencing makes them stationary. Thus, all the variables are non-stationary with integration of order one i.e. *I (1).*

Table 5: Results of Unit Root Tests of GDPPC and TRNINF index

	Augmented Dickey-Fuller Test		Phillips-Perron Test		
Variable's Name	at level	1st difference	at level	1st difference	Concluding Remark
$lnRODN$	1.2501	-4.5976^{***}	1.5378	-4.5785^{***}	I(1)
$lnRLDN$	1.4705	-6.1392^{***}	1.9046	-6.1392^{***}	I(1)
$lnARDN$	0.3879	-4.3504^{***}	0.3218	-4.3504^{***}	I(1)
$lnGDPPC$	-2.4362	-5.3375^{***}	-2.4459	-8.0168^{***}	I(1)
$TRNINF$	2.2517	-4.2445^{**}	2.8068	-7.3024^{***}	I(1)
$GDPPC$	0.6075	-4.1460^{**}	1.1112	-4.6031^{***}	I(1)

Notes: Here '***', is statistically significant at the 1% level. I (1) indicate non stationary nature of the variable with the integration of order one.
Source: Author's calculation.

b. Results

Results of ADF and PP test indicate that lnGDPPC, lnRODN, lnRLDN, lnARDN, and index of TRNINF and normalized GDPPC are integrated of order one i.e. all the variables are first difference stationary. In this context the present study applies two types of cointegration techniques – multivariate cointegration and bivariate cointegration. Engle and Granger (1987) showed that two I (1) time series may cointegrated if their linear combination is *I (0).* Existence of cointegration may exhibits a long run equilibrium relationship and in such situation error correction model can be applied to estimate the long-run relationship along with short-run dynamics among the variables. The next section below discusses the nexus between transport infrastructure and economic growth in a multivariate framework.

V.I. Multivariate Model

The multivariate analysis of the present study examines the cointegrating relationship[10] among lnGDPPC, lnRODN, lnRLDN, lnARDN. In this context, Johansen Co-integration test[11] (1988) is applied to find out whether any long run relationship exists among them. Table 6 reported the results of Johansen Co-integration test. Both Trace statistics and Max Eigen-value statistics indicate that there is one cointegrating equation among the variables, implies that all the variables are cointegrated.

Table 6: Results of Johansen Cointegration Test

No. of Co-integrating equations	Trace statistics	critical value	Max Eigen-value Statistics	critical value
None*	50.5429	47.8561	27.9102	27.5843
At most 1	22.6327	29.7971	16.0476	21.1216

Notes: Both the Trace and Max-Eigen value tests indicate 1 cointegrating equation at the 0.05 level. '*'denotes rejection of the hypothesis at the 0.05 level
Source: Author's calculation.

[10] The notion of cointegration can take care of the problem of spurious regression and check whether a causal relation exists between two or more non-stationary variables (Das, 2019).
[11] Johansen cointegration test requires non-stationary time series with same order of integration e.g. I (1) and I (2) (see Johansen, 1988 and 1995).

Cointegration provides long run equilibrium relationship between two or more non-stationary variables. However, it does not say anything about short-run forces that keep the long run equilibrium relationship intact (Bhaumik, 2015, pp. 273). In this context, the study applies vector error correction model (VECM) to assess the long-run relationship among road transport, rail transport, air transport, and economic growth in India along with short-run dynamics. The result of estimated long run relationship is presented in Table 7. The estimated long-run relationship between GDP per-capita and different modes of transport infrastructure is:

$$lngdppc = 5.2337 + 0.9085lnrddn + 0.1308lnardn \qquad (1)$$

Equation 1 indicates that an increase of one unit of lnrddn (road density) leads to an increase of 0.9085 unit of lngdppc (GDP per-capita) in the long-run. Similarly, an increase of 1 unit of lnardn (air density) raises 0.1308 unit of lngdppc in the long-run. The results thus reveal a positive and significant long-run relationship of road and air transports with economic growth in India. The coefficient of railway transport is found insignificant in the long-run.

Table 7: Estimated Long Run Relationship

Variable	Coefficient	Std. Error	t-statistics
$lnGDPPC$	1.0000		
$lnRODN$	-0.9085^{***}	0.1172	-7.7502
$lnRLDN$	-0.8380	1.0942	0.7658
$lnARDN$	-0.1308^{***}	0.0289	-4.5267
Constant	5.2337		

Notes: Here '***', is statistically significant at 1% level. Optimum lag length is 2 as per AIC, and SIC
Source: Author's calculation.

Table 8: Short run Dynamics

	Coefficient	Std. Error	t-statistics
ECT (-1)	-0.5613^{**}	0.2776	-2.0214

Notes: Here '**' is statistically significant at 10% level.
Source: Author's calculation.

The coefficient of the error correction term (ECT_{t-1}) is reported in Table 8. The coefficient of ECT_{t-1} is negative and statistically significant at 5% level. It indicates that any short run deviation from the long-run equilibrium relationship will automatically be corrected in the next year, and estimated speed of error correction is around 56 percent. It implies that the process will converge towards its long-run equilibrium value.

The study then performs some diagnostic tests to check the model's validity[12]. Results of the LM test, Jarque-Bera test, and CUSUM of squares test (see Table A1, Table A2 and Figure A2 in Appendix) suggest that the error correction equations are not subject to residually auto-correlated up to lag 2, normally distributed and stable.

The study further investigates the direction of causality among the variables. The direction of causation on the nexus between growth and transport infrastructure development is debatable and still an unsettled issue. However, this issue needs to be settled in the effective design and implementation of better transport policies for an emerging country like India. Therefore, the study applies VECM based causality test to assess the direction of causality, whether it is from transport infrastructure (or more specifically, different modes of transport infrastructure) to economic growth and vice versa.

Table 9: Results of VEC Granger causality/Block Exogeneity Wald test

Direction of causality	No. of Lags	Chi-square	Concluding remarks
Road transport ⟶ Economic growth	1	0.7273	Cannot reject H_0
Railway transport ⟶ Economic growth	1	0.1421	Cannot reject H_0
Air transport ⟶ Economic growth	1	0.4371	Cannot reject H_0
Economic growth ⟶ Road Transport	1	0.0917	Cannot reject H_0
Rail Transport ⟶ Road Transport	1	1.1489	Cannot reject H_0
Air Transport ⟶ Road Transport	1	0.3970	Cannot reject H_0
Economic growth ⟶ Railway Transport	1	1.2387	Cannot reject H_0
Road Transport ⟶ Railway Transport	1	0.4099	Cannot reject H_0
Air Transport ⟶ Railway Transport	1	0.1998	Cannot reject H_0
Economic growth ⟶ Air Transport	1	1.7002	Cannot reject H_0
Road Transport ⟶ Air Transport	1	**14.4952*****	**Reject H_0**

[12] Model's validity requires; residuals' series are normally distributed with no serial correlation and are stable.

Rail Transport	→ Air Transport	1	3.9536	Cannot reject H_0

Notes: Here '***' is statistically significant at 1% level.
Source: Author's calculation.

Table 9 presented the results of Wald test. The test does not reject the null hypothesis of non-causality in case of any of the mode of transport infrastructure to economic growth and vice versa. This implies that in the short-run neither any sub-sector of transport infrastructure causes economic growth nor economic growth causes them. However, the study finds a short-run causation from road transport to air transport, implying that growth of road transport infrastructure is a pre-condition for the growth of air transport infrastructure.

Overall, from the multivariate analysis, it is observed that road, rail, and air transport infrastructures are cointegrated with economic growth in India. Road and air transports have a positive and significant long-run relationship with economic growth. However, no short-run causality is found from any of the sub-sector of transport infrastructure to economic growth and vice versa.

The analysis of above said multivariate level variables may have some limitations, if any. As per literature there is also certain problem in bivariate levels. To overcome these problems and to re-examine the nexus between growth and infrastructure development focusing transport infrastructure, this study designs a time series composite index of transport infrastructure using principal component analysis (PCA). The corresponding Eigen values and the different principal components for each sub-sectors of transport infrastructure are reported in Table A6 and Table A7 in Appendix. Design of composite index of transport infrastructure will reduce the dimension of the data set and make them unit free. Despite this, it also provides relevant coefficients of all the three indicators rather incorporating them into a single equation. In the section below we discuss the empirical results between transport infrastructure index and normalized GDP per capita or income index.

V.II. Nexus between Transport Infrastructure index and Income index

ADF and PP unit roots tests (See Table 5) suggest that transport infrastructure index (TRNINF) and income index (GDPPC) are non-stationary and having integrated in order one i.e. *I (1)*. Therefore, cointegration can be tested between GDPPC and TRNINF. Engle and Granger test of cointegration applies ADF test on residuals (see Table 10) of the estimated cointegrating equation:

$$GDPPC = -0.027 + 0.500\,TRNINF + 0.007\,t \text{ .... } (2)$$

Table 10 indicates that estimated residual series generated from Equation 2 is stationary at level as the ADF test rejects the null hypothesis of having unit roots at 1% level.

Table 10: Results of Unit Root Test of the estimated residuals of Equation 1

Augmented Dickey-Fuller Test at level			
	t-statistics	p-value	variable's type
Residual	-4.8720***	0.0030	I(0)

Notes: '***' is statistically significant at 1% level.
Source: Author's calculation.

The result indicates that transport infrastructure and economic growth are cointegrated and a long run equilibrium relationship may exist between them. In such situation, Granger causality test can be applied to assess the direction of causality. Table 11 presents the estimated results of long-run relationships along with short run dynamics.

Table 11: Estimated Long-run and Short-run dynamics between GDPPC and TRNINF index

Variables	Coefficient	Std. Error	t- statistics	Prob.
TRNINF	0.5000***	0.0242	20.6300	0.0000
Trend	0.0071***	0.0015	4.8595	0.0001
Constant	-0.0279**	0.0107	-2.5962	0.0156

ECT (-1)	-0.5668**	0.2302	-2.4620	0.0230
R^2	0.9959			
Adj. R^2	0.9956			
DW	1.9104			
Sum sq. Resid.	0.0103			
Log Likelihood	70.9503			
F-statistics	3073.98			
AIC	-4.8536			
SIC	-4.7109			

Notes: '***' and '**' denote the level of significance at 1% and 5%, respectively.
Source: Author's calculation.

The study applies ordinary least square (OLS) method to estimate the long-run relationship between transport infrastructure and economic growth. Equation 1 shows the estimated long-run relationship between transport infrastructure and economic growth. Equation 1 indicates that normalized per-capita income increases by 0.50 points for every incremental point of transport infrastructure index to maintain the long-run equilibrium, *Ceteris peribus*. Thus, in the long-run transport infrastructure has a positive relationship with economic growth in India in the period of post liberalization. Time trend is also positive and significant and bears a positive relationship with economic growth. The negative and significant error correction term indicates that transport infrastructure would make a short run adjustment at an approximate speed of 57% towards its long-run equilibrium path whenever there induce any shock to the system, respectively. The study then performs some diagnostic tests to check whether the model is free from serial correlation, whether the residuals of the error are normally distributed and finally, whether the model is stable or not. The results of LM test, Jarque-Bera test, and CUSUM of squares test are reported in Table A3, Table A4 and Figure A3 in the Appendix.

In such situation, Granger causality test may be applied to assess the direction of causality. So, the study further performs vector autoregressive (VAR) base Granger causality (Granger, 1969) test to assess the direction of causality between overall transport infrastructure and economic growth.

In this context, we examine optimum lag length for VAR model. The optimal lag length is one as per AIC and SIC (see Table A5 in Appendix). The results of Granger causality test are presented in Table 12.

Table 12: VAR Granger Causality/Block Exogeneity Wald Tests

Causal Relation	Chi-Square	Prob.	Remark
Δ(TRNINF) ⟶ Δ(GDPPC)	11.8879***	0.0026	Causality Exists
Δ(GDPPC) ⟶ Δ(TRNINF)	23.6353***	0.0000	Causality Exists

Notes: '***' is statistically significant at 1% level. Lag length for the model is 1 as per SIC and AIC. Here, x ⟶ y means x is a cause of y.
Source: Author's calculation.

The result of the causality test indicates that transport infrastructure causes economic growth and economic growth is also a cause of transport infrastructure in the short-run. This indicates the existence of bidirectional causality between transport infrastructure and economic growth.

There has been a long debate between endogenous growth theories and Wagner's law on the issue of direction of causality between infrastructure and economic development. Empirical literature was unable to confirm whether the causality is from infrastructure to economic development or vice versa. The findings of this study may settle the above said issue and definitely help to form appropriate transport policies for an economy which aspires to grow.

VI. Conclusion

This study has reinvestigated the relationship between transport infrastructure and economic growth in the post liberalization era in India. For the said purpose, we have collected data from the RBI and the CMIE for the period of 1990-2017. Applying techniques of unit root tests, we have examined the nature of data and observe that concerned variables are non-stationary i.e. I(1). Next, the study investigates the cointegrating long run equilibrium relations. This investigative study has done in two ways using (i) multivariate level variables and (ii) unit free bivariate index variables. To make unit free this study constructs a composite index for transport infrastructure using the principal component analysis (PCA). This composite index represents overall transport infrastructure.

Initially, this study applies a multivariate dynamic framework to examine the nexus between economic growth and transport infrastructure in general, and different modes of transport namely road, rail, and air transport infrastructure with economic growth in particular. Applying econometric techniques this study confirms the cointegrating relationship between economic growth and transport infrastructure. Using cointegration and Granger causality test, the results of the present study may be summarized as follows:

a. Economic growth is directly related with road and air transport. Road transport infrastructure has a significant positive contribution to economic growth in the long-run. This indicates that an increase in road transport would have a positive effect on economic growth in the long-run. In the long-run, air transport has also a played an important role in economic growth in India. No significant long-run relationship is found between railway infrastructure and economic growth in India. This could be due to the fact that in the post globalization era, the extension of railway network (total railway length) has not been increased much and remained constant over the years (see Figure A1 in Appendix). The results of the Granger causality test from the multivariate dynamic frame work suggest no short-run causality from any of the sub-sector of transport infrastructure to economic growth and vice versa.

b. Unit free bivariate model is used replacing the multivariate model. Results of unit free bivariate model provide long run relation between transport infrastructure and economic growth with short run dynamics. Overall transport infrastructure is reflected in transport infrastructure index, which is significant in the long-run and has a positive contribution to the economic growth in India since 1990. However, bidirectional causality exists between overall transport infrastructure and economic growth in the short run, indicating that expansion of transportation system will cause economic growth and on the contrary, high growth in per-capita income will also facilitate the demand for transport infrastructure.

From the policy perspective, the results of the present study suggest that increasing transport facilities (namely road, rail, and air) might be an effective way through which sustainable economic growth can be achieved. An extra care should be taken to increase the total railway length as it is more environment friendly than other sub-sectors of transport infrastructure.

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Appendix

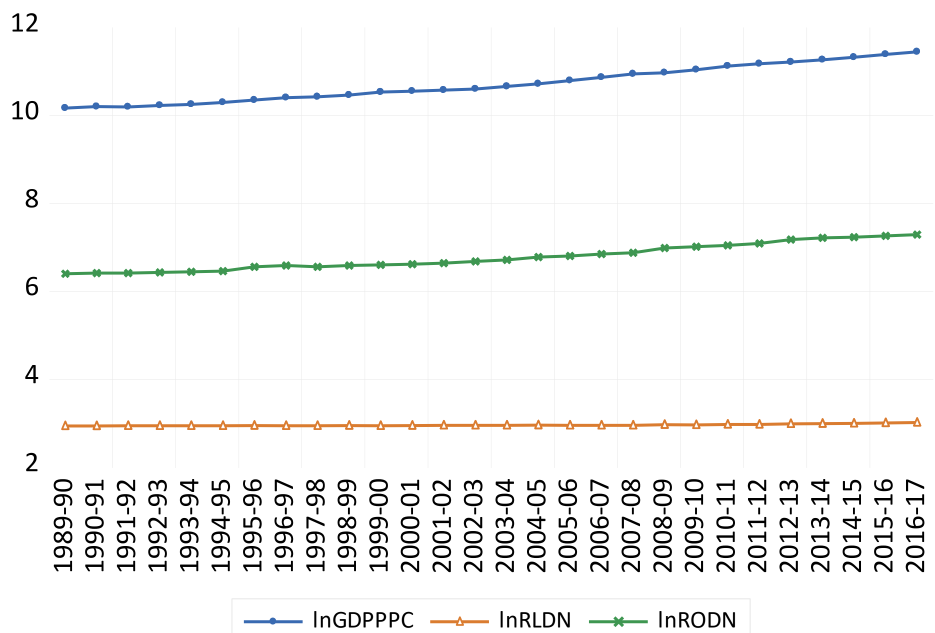
$$\begin{bmatrix} \Delta \ln gdppc_t \\ \Delta \ln rodn_t \\ \Delta \ln rldn_t \\ \Delta \ln ardn_t \end{bmatrix} = \begin{bmatrix} \alpha_{10} \\ \alpha_{20} \\ \alpha_{30} \\ \alpha_{40} \end{bmatrix} + \sum_{i=1}^{p} \begin{bmatrix} \alpha_{11i} & \alpha_{12i} & \alpha_{13i} & \alpha_{14} \\ \alpha_{21i} & \alpha_{22i} & \alpha_{23i} & \alpha_{24i} \\ \alpha_{31i} & \alpha_{32i} & \alpha_{33i} & \alpha_{34i} \\ \alpha_{41i} & \alpha_{42i} & \alpha_{43i} & \alpha_{44i} \end{bmatrix} \begin{bmatrix} \Delta \ln gdppc_{t-i} \\ \Delta \ln rodn_{t-i} \\ \Delta \ln rldn_{t-i} \\ \Delta \ln ardn_{t-i} \end{bmatrix} + \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \lambda_3 \\ \lambda_4 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \quad \text{(1a)}$$

$$\Delta\hat{\varepsilon}_t = \alpha\hat{\varepsilon}_{t-1} + \sum_{i=1}^{\rho} \beta_i \Delta\hat{\varepsilon}_{t-i} + \mu_t \quad \text{(1b)}$$

$$J_{trace} = -T\sum_{i=r+1}^{n} ln\,(1 - \hat{\rho}_i \quad \text{(1c)}$$

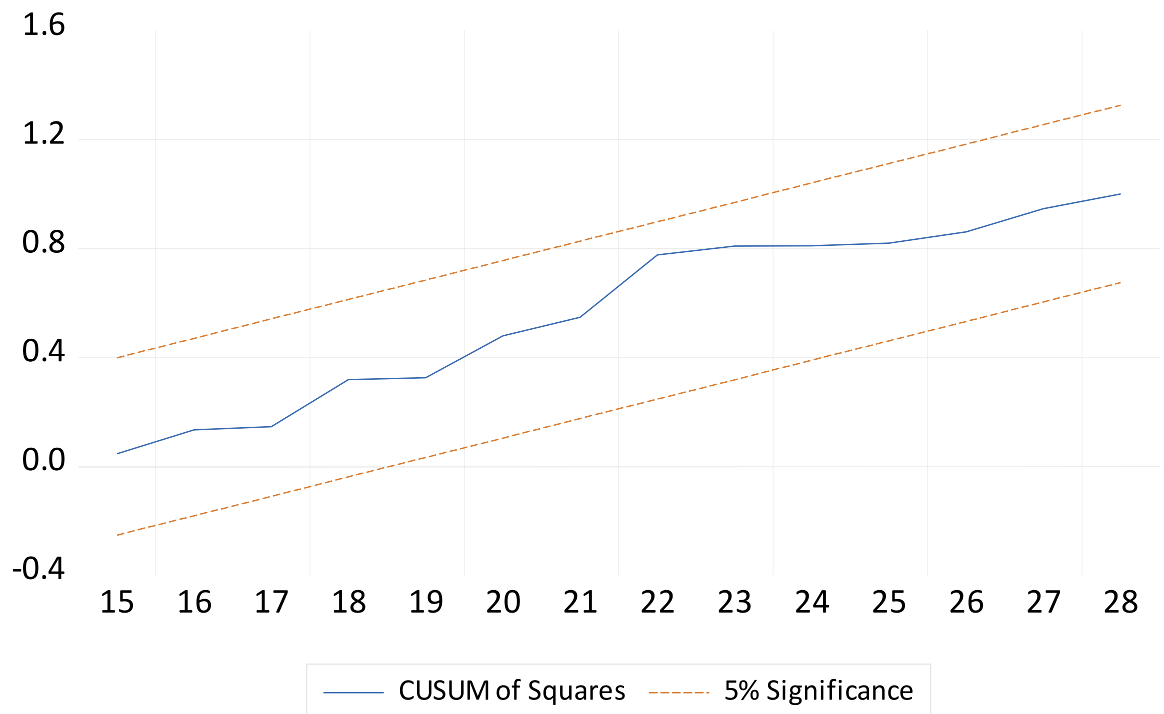
$$J_{max} = -Tln(1 - \hat{\rho}_{r+1} \quad \text{(1d)}$$

Fig A1: log GDP per capita, log Road density and log Rail density in India during 1989-90 to 2016-17



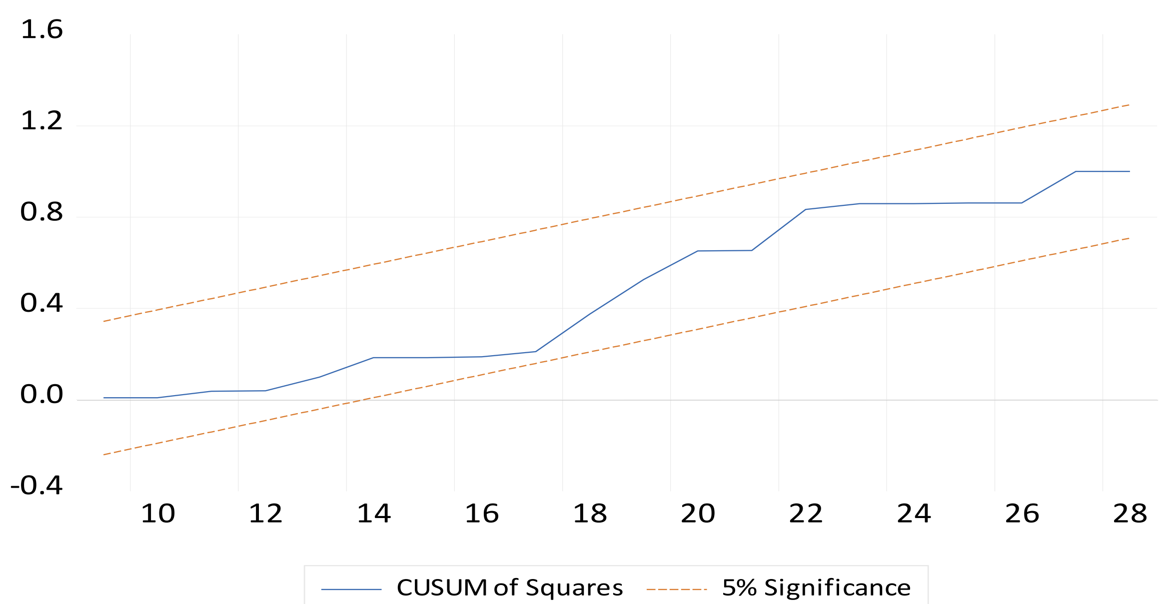
Source: Author's calculation.

Fig A2: CUSUM of Squares test for model stability



Source: Author's calculation.

Fig A3: CUSUM of Squares test for model stability



Source: Author's calculation.

Table A1: Results of Breusch-Godfrey Correlation LM test

F-statistic	p-value	Remarks
1.5466	0.2526	Cannot reject

Source: Author's calculation.

Table A2: Results of Jarque-Bera Normality test

F-statistic	p-value	Remarks
0.6931	0.7070	Cannot reject

Source: Author's calculation.

Table A3: Results of Breusch-Godfrey Correlation LM test

F-statistic	p-value	Remarks
0.0011	0.9732	Cannot reject

Source: Author's calculation.

Table A4: Results of Jarque-Bera Normality test

F-statistic	p-value	Remarks
0.6709	0.7150	Cannot reject

Source: Author's calculation.

Table A5: Lag order selection criteria for the VAR model

Lag	LR	FPE	AIC	SIC	HQIC
Optimum lag length for per capital GDP and Road Transport					
0	NA	0.000206	-2.813946	-2.717169	-2.786078
1	160.7962*	2.58e-07*	-9.497395*	-9.207065*	-9.413790*
2	2.616652	3.12e-07	-9.314305	-8.830422	-9.174964

'*' indicates lag order selected by the criterion
LR: sequential modified LR test statistic (each test at 5% level)
FPE: Final prediction error
AIC: Akaike information criterion
SC: Schwarz information criterion
HQ: Hannan-Quinn information criterion
Source: Author's calculation.

Table A6: Eigenvalues and Variance explained by Principal Components

Principle Components	Eigenvalues	Percentage of variance	Cumulative variance
1	2.9327	0.9776	0.9776
2	0.0526	0.0175	0.9951
3	0.0146	0.0049	1.0000

Source: Author's calculation.

Table A7: Components loadings for different sub-sectors of Transport Infrastructure

Variable	PC 1	PC 2	PC 3
Road Density	0.580503	-0.230756	-0.780877
Rail Density	0.573947	0.796214	0.191384
Air Density	0.577582	-0.559281	0.594646

Source: Author's calculation.