Transport Infrastructure, Energy Consumption and Economic Growth Triangle in India: Cointegration and Causality Analysis

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Abstract

The paper explores the nexus between transport infrastructure (road and rail), energy consumption (oil and electricity) and economic growth in India over the period 1970-2007. Using cointegration and Granger causality test, the paper finds a unidirectional causality from transport infrastructure to economic growth, a unidirectional causality from economic growth to energy consumption and a unidirectional causality from transport infrastructure to energy consumption. The paper at the end suggests that energy and transportation policies should recognize the transport- energy consumption- growth nexus in order to maintain sustainable economic growth in the country.

Keywords: Transport infrastructure, Energy consumption, Economic growth

1. Introduction

Transport is an essential element of the modern society and key to sustained economic growth (Ramanathan, 2001; Banister and Berechman, 2001; Ramanathan and Parikh, 1999; Eisner, 1991). Adequacy of this vital infrastructure is an important determinant of the success of a nation's effort in diversifying its production base, expanding trade and linking together resources and markets into an integrated economy. However, the success of this sector is highly dependent upon the level of energy in the economy. In fact, transport sector is the largest user of energy in the economy (Reddy et al., 2001; Samimi, 1995). The consumption of energy is likely to grow up further with economic growth, population growth, rapid industrialization, urbanization and agricultural modernization (Ramanathan and Parikh, 1999). The key question is that whether transport promotes energy consumption in the economy, particularly in India. Theoretically, transport and energy are well integrated. On the one side, energy is a component to transport and on the other side, transport is a key determinant to energy. The nexus between the two, however, are not received adequate attention. This is the major issue that we investigate in this paper. Besides, we like to know, whether they have connection with economic growth.

The literature provides many works on energy-growth nexus (Bowden and Payne, 2009; Odhiambo, 2009; Wolde-Rufael, 2009; Chiou-Wei et al., 2008; Narayan and Smyth, 2008; Yuan et al., 2008; Squalli, 2007; Morimoto and Hope, 2004; Oh and Lee, 2004; Glasure, 2002; Aqeel and Butt, 2001; Cheng, 1999; Glasure and Lee, 1997; Hwang and Gum, 1991) and transport-growth nexus separately (Broadstock and Hunt, 2010; Herranz-Lonca, 2007; Esfahani and Ramirez, 2003; Majumder, 2003; Jiang, 2001; Kulshreshtha et al., 2001; Munnell, 1992). But there is very less work on the nexus between transport, energy consumption and economic growth (Anson and Turner, 2009; Poudenx, 2008; Bauer et al., 2003; Lim, 1998). The study has many implications. It not only provides an insight with respect to the role of transportation on energy consumption and economic growth but also provides a basis for discussion of energy and transportation policies in the economy. For instance, a unidirectional causality running from transportation to energy consumption and economic growth implies that energy consumption and economic growth are dependent on transportation and a decrease in transport may restrain energy consumption as well as economic growth. Similarly, a unidirectional causality from economic growth to transportation and energy consumption represents that energy consumption and transportation depends upon economic growth. A substantial decline of economic growth may affect the level of transportation and energy consumption.

The residual of the paper is organized as follows: Section II describes econometric methodology and data descriptions. Section III follows empirical results and its discussion thereof. The final section offers conclusion and policy implications.

2. Data Set and Econometric Methodology

Several ways transport and energy can be presented. The study is, however, restricted to road and rail transport for transport infrastructure and oil consumption and electricity consumption for energy consumption. It is believed that other variables could have great impact on economic growth. The omission of these variables could bias the direction of causality between transport infrastructure and economic growth. In view of this, we included one more control variable such as gross capital formation to avoid simultaneous bias in our regression. Data used in this analysis are annual time series for India during 1970-2207. The data are obtained from World Development Indicators, World Bank and Centre for Monitoring Indian economy, Mumbai. The Table 1 provides the summary statistics for each variable.

There are two ways we can model the nexus between transport, energy and economic growth: production function approach and causality approach. The first model is regression based approach, where there is no

discussion on causality (Donaldson et al, 1990). Moreover, this model does not highlight the unit root and cointegration problems. The second model is purely based on causality approach, where the unit root and cointegration have been taken into consideration. The paper is all about on causality approach. Note that all these variables are used in natural logarithms so that their first differences approach the growth rates. The cointegration and Granger causality test have been applied to trace the nexus between transport, energy consumption and economic growth. Engle and Granger (1987) showed that, if two variables are individually integrated of order one and cointegrated then there is possibility of a causal relationship in at least one direction.

The detail procedure of modelling the nexus between economic growth and transport infrastructure is as follows:

Step 1: Normalization and aggregation of the transport and energy data. For a particular variable X, the normalization and aggregation can be done on the following ways:

$$I_i(X_i) = X_i \Big/ X_i^{\max} \qquad\qquad \text{………..……. (1)}$$

$$I(X) = \frac{1}{n} \sum_{i=1}^{n} I_i(X_i) \qquad\qquad \text{………..……. (2)}$$

Where, $X_i^{\max}$ denotes maximum of variable i and I (X) represents the composite index for transport and energy. The results of this index are shown in Figure 1.

Step 2: Test the order of integration to know the stationarity of these time series variables.

Step 3: Test the cointegration to know the existence of long run equilibrium relationship between them.

Step 3: Granger causality test to assess the short run cointegration and the direction of causality between the variables.

The detail econometric approach of these three tests is described below:

2.1 Test for Order of Integration

The test for order of integration means to know the stationarity of the time series variables. The Phillips and Peron (PP) unit root test is applied to detect the order of integration. This is a non-parametric test to the conventional t-test that is robust to a wide variety of serial correlation and time dependent heteroskedasticity. The PP unit root test requires estimation of the following equation (Phillips and Perron, 1988);

$$X_t = \alpha_t + \sum_{i=1}^{T} X_{t-T} + \varepsilon_t \qquad\qquad \text{………..……. (3)}$$

The bias in the error term results when the variance of the true population is as follows:

$$\sigma^2 = \lim_{T \to \infty} E\left(T^{-1} S_T^2\right) \qquad\qquad \text{………..…….(4)}$$

Differs from the variance of the residuals in the regression equation:

$$\sigma_u^2 = \lim_{T \to \infty} T^{-1} \sum_{t=1}^{T} E\left(U_t^2\right) \qquad\qquad \text{………..……. (5)}$$

Consistent estimators of σ^2 and σ_u^2 are:

$$S_u^2 = T^{-1} \sum_{t=1}^{T} \left(U_t^2\right) \qquad\qquad \text{………..……. (6)}$$

$$S_{TK}^2 = T^{-1} \sum_{t=1}^{T} \left(U_t^2\right) + 2 T^{-1} \sum_{t=1}^{K} \sum_{t=j+1}^{T} u_t u_{t-j} \qquad\qquad \text{………..……. (7)}$$

Where k is lag truncation parameter, which is used to ensure that the autocorrelation of the residual is fully captured. The equation (7) represents that when there is no autocorrelation the last term in the formula defining S_{TK}^2 is zero and $\sigma_u^2 = \sigma^2$. The PP test-statistic [Z(t$_\mu$)] under the null-hypothesis of I (0) is

$$Z(t_\mu) = \langle S_u \,|\, S_{tk} \rangle t_\mu - \frac{1}{2}\left(S_{tk}^2 - S_u^2\right)\left[S_{tk}\left\{ T^2 \sum_{t=2}^{T} (Y_t - Y_{t-k})^2 \right\}^{\frac{1}{2}} \right]^{-1} \qquad\qquad \text{…. (8)}$$

Let us assume "d" is the number of times that a variable needs to be differenced in order to attain stationarity. Such variable is said to be integrated of order "d" and denoted by I (d). If the variable is stationary at the level data, it is integrated of order zero [I (0)]. Similarly if the variable is stationary at the first difference, it is integrated of order one [I (I)] and if the variable is stationary at the second difference, it is integrated of order two [I (2)] and so on.

2.2 Testing for Cointegration

The Cointegration test is meant to know the existence of long run equilibrium relationship between the variables. The long run equilibrium relationship, as a statistical point of view, means the variables move together over time

so that short term disturbances from the long term trend will be corrected. A lack of cointegation suggests that such variable have no long run equilibrium relationship and in principle, they can wander arbitrarily far away from each other (Dickey et al., 1991). Note that regression among integrated series is meaningful, if they involve cointegrated variables.

The Johansen (1988) maximum likelihood (ML) test is applied to examine the cointegration between transport infrastructure and economic growth. The econometric procedures of these statistics are as follows:

Let X_t be a (n X 1) vector of variables with a sample of t. Assuming X_t follows I (1) process, identifying the number of cointegrating vector involves estimation of the vector error correction representation:

$$\Delta X_t = A_0 + \prod X_{t-p} + \sum_{i=1}^{p-1} A_i \Delta X_{t-i} + \varepsilon_t$$ ………..……. (3)

Where, vector ΔX_t and ΔX_{t-1} are I (1) representation. The long run equilibrium relationship among X_t is determined by the rank of Π (say r) is zero, then equation (3) can be transferred to a VAR model of pth order and the variables in level do not have any cointegrating relationship. If $0 < r < n$, then there are n X r matrices of α and β such that

$$\Pi = \alpha\beta'$$ ………..……. (4)

Where, both α and β are (n x r) matrices. The cointegrating vectors β have the property that $\beta' X_t$ is stationary [I (0)] even though X_t is non-stationary [I (1)]. Johansen likelihood ratio test looks for two statistics: trace statistics and maximum eigen value.

The likelihood ratio test statistic for the null hypothesis that there are at most r cointegrating vectors is the trace test and is computed as:

$$Trace = -T \sum_{i=r+1}^{n} Log\left(1 - \hat{\lambda}_i\right)$$ ………..……. (5)

Where $\hat{\lambda}_{r+1}, \ldots.. \hat{\lambda}_n$ are (n-r) smallest estimated eigen values.

The likelihood ratio test statistic for the null hypothesis of r cointegrating vectors against the alternative of r + 1 cointegrating vectors is the maximum eigen value test and is given by

$$\lambda_{max} = -TLog\left(1 - \hat{\lambda}_{r+1}\right)$$ ………..……. (6)

Here, the null hypothesis of r cointegrating vectors is tested against the alternative hypothesis of r +1 cointegrating vectors. Hence the null hypothesis r = 0 is tested against the alternative r = 1, r =1 against the alternative r = 2, and so forth. It is well known that the cointegartion tests are very to the choice of lag length. The Schwarz Bayesian Criterion (SBC) is used to select the number of lags required in the cointegration test.

2.3 Granger Causality Test

The Granger causality test (Granger, 1988) is applied to examine the causality between transport, energy consumption and economic growth in India. The model is used for the same is as follows

$$TRAINF_t = \phi_1 + \sum_{i=1}^{n} \alpha TRAINF_{t-i} + \sum_{j=1}^{n} \beta ENEINF_{t-j} + \sum_{k=1}^{n} \delta GDP_{t-k} + \xi_t$$ ……. (9)

$$ENEINF_t = \phi_1 + \sum_{i=1}^{n} \alpha TRAINF_{t-i} + \sum_{j=1}^{n} \beta ENEINF_{t-j} + \sum_{k=1}^{n} \delta GDP_{t-k} + \xi_t$$ ……. (10)

$$GDP_t = \phi_1 + \sum_{i=1}^{n} \alpha TRAINF_{t-i} + \sum_{j=1}^{n} \beta ENEINF_{t-j} + \sum_{k=1}^{n} \delta GDP_{t-k} + \xi_t$$ ……. (11)

Where, GDP stands for economic growth, TRAINF stands for composite index of transport infrastructure and ENEINF stands for composite index of energy infrastructure. To select an appropriate lag length, we use Schwarz Bayesian Criterion.

3. Results and Discussion

The Table 2 presents the estimated results of PP test. The results indicate that the time series variables are non-stationary in their levels but found stationary in the first differences. That means they are integrated of order one [I (1)] and confirms the possibility of long run equilibrium relationship between them. Using Johansen cointegration test, it is however confirmed that there is no cointegrating vector (see Table 3). This suggests that there is no long run equilibrium relationship between transport infrastructure, energy consumption and economic growth. However, we can study the direction of causality by simple Granger framework. The estimated results of Granger causality test are reported in Table 4. The results showed that there is unidirectional causality from transport infrastructure to economic growth (TRAINF => GDP). This is justified on the basis of F-statistics, which is significant at (1, 1) and (2, 2) lag level. The reverse causality is, however, not found in the present case. The unidirectional causality is also found from economic growth to energy consumption and is supported by F-statistics at (1, 1) and (2, 2) lag level. This represents that it is the economic growth which determines the level

of energy consumption but energy consumption does not influence the economic growth. The results also confirmed the uni- directional causality from transport infrastructure to energy consumption in the economy. The reverse causality is, however, not found in the present study. The summary of the causality results at (2, 2) are represented in Table 5. The entire analysis sums up that transport is an effective infrastructure for energy consumption and economic growth in the Indian economy. The quantification indicates that a positive change in transport infrastructure leads to a positive change in both energy consumption and economic growth. The findings are very essential for the policy makers for enhancing the transport infrastructure in the economy for the benefit of energy consumption and economic growth.

4. Conclusion

Understanding the nexus between transport infrastructure, energy consumption and economic growth is very vital in the effective design and implementation of transport policies and energy policies in the economy. The present study explores the same in India during 1970-2007. Using cointegration and Granger causality test, it concludes the following:

1) A unidirectional causality running from transport infrastructure to economic growth.

2) A unidirectional causality running from economic growth to energy consumption.

3) And a unidirectional causality from transport infrastructure to energy consumption.

To conclude, transport is a key infrastructure in the present study, as causes energy consumption as well as economic growth. It is, therefore, suggested that increasing transport facility along with energy consumption will lead to more economic growth in India. The achievement of higher economic growth through transport infrastructure and energy consumption could be due to its various direct and indirect benefits in the economy. But in India, the level of transport infrastructure is not so good, both in quantity and quality, in contrast to developed countries in the world. The result would be much better, if there is sufficient transport infrastructure in the economy. Since transport infrastructure is a big deal to economic growth, a suitable transport policy should be required urgently to boost economic growth and to maintain sustainable economic development in the country. A piecemeal approach to such a vital issue is of serious consequences and may affect economic growth in the long run. Therefore, government has to look the same at any cost and with a greater caution.

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Table 1. Summary Statistics

Panel A: Univariate Statistics			
Statistics	TRAINF	ENEINF	GDP
Mean	0.773	0.627	0.339
Median	0.767	0.607	0.297
Standard Deviation	0.104	0.196	0.224
Maximum	0.617	0.373	0.072
Minimum	1.000	1.000	1.000
Q_3	0.693	0.435	0.174
Q_1	0.836	0.813	0.453
Panel B: Cross- Correlation			
TRAINF	1.0000		
ENEINF	0.965	1.0000	
GDP	0.968	0.96	1.000

Note: TRAINF: Composite index of transport Infrastructure; ENEINF: Composite index of energy infrastructure; GDP: Gross Domestic Product.

Table 2. Unit Root Test Results

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Level Data		First Differences		
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C	C +T	C	C +T	Conclusion

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Variables

TRAINF	0.129	-2.65	-7.16*	-8.02*	[1 (1)]
ENEINF	0.471	-2.12	-3.77*	-3.74*	[1 (1)]
GDP	-0.55	-2.00	-4.18*	-4.16*	[1 (1)]

Critical Values (at 10 %)

TRAINF	2.61	-3.20	2.61	-3.20
ENEINF	2.61	-3.20	2.61	-3.20
GDP	2.61	-3.20	2.61	-3.20

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Note:

1) TRAINF: Composite index of transport infrastructure; ENEINF: Composite index of energy infrastructure;
GDP: Economic growth; GCF: Gross capital formation; C: Constant; C+T: Constant and trend.

2) PP test is use with trend and no trend.

3) The lag length has been choosen based on minimum of AIC.

4) The critical values follow MacKinnon and James, 1996.

5) * implies significant at 1% level.

Table 3. Results of Cointegration Test

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Null Hypothesis	Trace Statistics	5 % Critical Value	Max Eigen Value	5 % Critical Value

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H_0: r = 0	18.16	29.78	12.398	21.132
H_0: r ≤ 1	5.765	15.495	5.505	14.265
H_0: r ≤ 2	0.260	3.841	0.260	3.841

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Note:

1) r denotes the number of cointegrating vectors.

2) The Estimation process follows linear deterministic trend.

3) The critical values follow MacKinnon-Haug-Michelis, 1999.

Table 4. Results of Granger Causality Test

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Causal Relationships (1, 1) (2, 2)	Null Hypothesis Conclusion	F		

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GDP and TRAINF	GDP => TRAINF	0.851	0.461	X
	TRAINF => GDP	13.96*	7.068*	√
GDP and ENEINF	GDP => ENEINF	12.31*	3.873*	√
	ENEINF => GDP	0.704	1.235	X
ENEINF and TRAINF	ENEINF => TRAINF	2.795	1.985	X
	TRAINF => ENEINF	3.163*	2.720*	√

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Note:

* implies significance level; X: indicates the absence of causality; √: indicates the presence of causality; other notations are defined earlier.

Table 5. Results of Vector Auto regression Estimates

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Variables	T (-1)	T (-2)	P (-1)	P (-2)	G (-1)	G (-2)	R^2	F	AIC SBC

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T	0.797	-0.041	-0.427	0.475	0.0127	0.015	0.972	157	-6.19-5.876
	[4.31]	[-0.91]	[-1.25]	[1.48]	[0.19]	[0.25]			
P	-0.046	0.095	1.251	-0.313	0.043	-0.020	0.998	3317	-7.42-7.107
	[-0.46]	[0.81]	[6.76]	[-1.801]	[1.23]	[-0.62]			
G	1.36	-0.06	-0.372	0.322	0.976	-0.214	0.99	459	-4.053 -3.739
	[2.53]	[-0.10]	[-0.37]	[0.344]	[5.13]	[-1.206]			

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Note:

T stands for composite index of transport infrastructure; P stands for composite index of energy; G stands for economic growth; other notations are defined earlier.
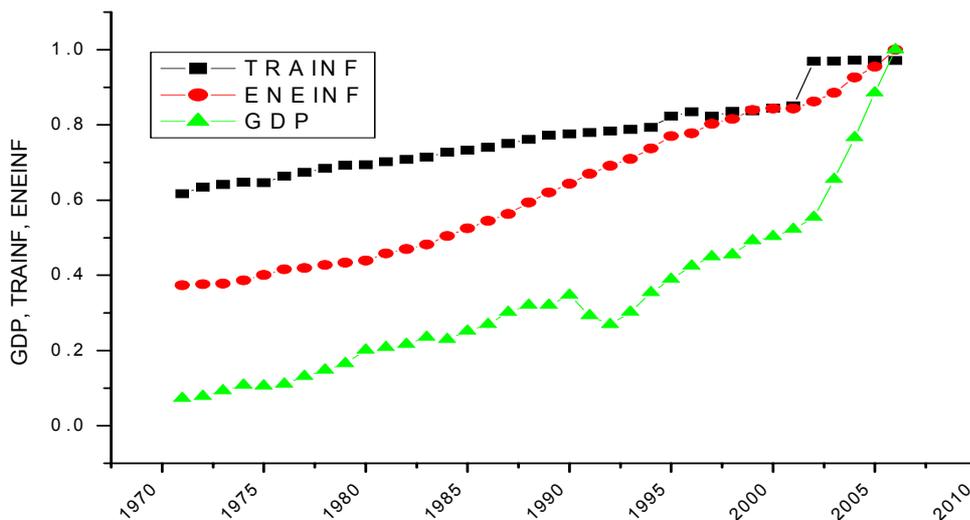

Figure 1. The Visual Plots of Economic growth, Energy Consumption and Transport Infrastructure