Analyzing the Dynamic Relationship between Physical Infrastructure, Financial Development and Economic Growth in India

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Ranjan Kumar Mohanty and N. R. Bhanumurthy

National Institute of Public Finance and Policy
New Delhi

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Abstract

The paper investigates dynamic relationship between physical infrastructure, financial development and economic growth in the case of India, using an Autoregressive Distributed Lag (ARDL) and Toda-Yamamoto (T-Y) causality approach for the period 1980 to 2016. Physical infrastructure index and financial development index are constructed using Principal Component Analysis method. Empirical results suggest that physical infrastructure has a positive effect on economic growth both in the long-run and short-run, whereas financial development, though significant, has a weak impact on economic growth. The causality test supports a bi-directional causal relationship between infrastructure development and economic growth, while it finds a unidirectional causation running from economic growth to financial development. It also finds that gross investment and employment have a positive, and inflation has an adverse effect on economic growth. As India is aiming for higher growth for a sustained period, our results suggest that there is a need for Government intervention in expanding the physical infrastructure and this, in turn, could lead to the growth of the financial sector in the country.

Keywords: Infrastructure Index, Financial Development Index, Economic Growth, ARDL Approach, India
JEL Classification codes: H40, C43, O40, C32

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1. Introduction

Infrastructure and financial sector are two crucial factors for any economic progress. A well-developed financial system and better infrastructure are expected to boost growth and inclusiveness. In the case of India, which is being identified as one of the fastest growing large economies in the world, although both the infrastructure and financial sector have been expanded significantly, still there exist large gaps. To sustain the high growth momentum and to make such growth inclusive, there is a need to understand the role and extent of infrastructure facilities and financial development required. Therefore, an attempt is made to examine the impact of physical infrastructure and financial development along with other control variables on economic growth in India.

There are two types of infrastructure: physical and social. Physical infrastructure development is an essential driving force for achieving rapid economic growth. Higher investment in physical infrastructure reduces transaction costs as well as other input costs, fosters trade and investment, opens up new markets, improves competitiveness, creates employment opportunities, raises productivity, and stimulates economic activities, which contributes to economic growth. Provision of social infrastructures such as expenditure on education and health services endows the economy with skilled and productive human capital, which also leads to an increase in productivity and growth but in the long-run. Greater access, especially for the deprived population, to transport, telecommunications, energy, electricity, water and sanitation, education and health services are needed to bring inclusive growth and development. All these facilities play both direct and indirect role in the development process by increasing the factor productivity of land, labor, and capital in the production process, which promotes economic growth. Lack of infrastructure continues to be a major obstacle to achieve growth and development. Recently, the Indian government estimated that there is a need for nearly $4.5 trillion for reducing physical infrastructure deficit in the country.[1]

There are a number of studies in the existing literature that looks at links between infrastructure and economic growth by using cross-sectional, time series, and panel data analysis. Previous literature has emphasized clearly the role of infrastructure development in economic growth (Devarajan et al., 1996; Demurger, 2001; Wang, 2002; Esfahani and Ramires, 2003; Zhang and Fan, 2004; Feddeke, Perkins and Luiz, 2006; Loncan, 2007; Fedderke and Bogetic, 2009; Helm, 2009; Luoto, 2011; Kuhl and Mussolin, 2012; Zhang et al., 2014; Batuo, 2015 etc.). Many of the studies also found that there is unidirectional/bi-

1) https://www.thehindubusinessline.com/economy/piyush-goyal-capital-cost-for-45-trillion-infra-investment-a-challenge/article24251518.ece

directional causality between infrastructure and economic growth (Roller and Waverman, 2001; Canning and Pedroni, 2008; Pradhan and Bagchi, 2013; Singh and Bhanumurthy, 2014; Pradhan et al., 2014). Besides, some regional studies in India such as Fan et al., (2000), Lall (2007), and Sahoo and Dash (2009, 2012) suggest that physical infrastructure such as transportation, communication, power, and telephones promote efficiency and later economic growth. Most of these studies conclude that infrastructure development has a positive and significant effect on economic growth.

In addition to infrastructure, another factor that could affect growth positively, and is widely identified in the literature, is the extent of financial development. The emergence of endogenous growth literature has generated renewed interest in the positive role of financial development in driving economic growth (Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991; King and Levine, 1993a). Developed financial systems promote economic growth by mobilizing savings, allocating resources to the most productive investments, reducing information, transaction and monitoring costs, diversifying risks, and encouraging innovation. Thus, it eventually leads to economic growth because of more efficient resource allocation, accumulation of physical and human capital, and faster technological progress. The positive relationship between financial development and economic growth are supported in the literature (Gurley and Shaw, 1955; Greenwood and Jovanovic, 1990; Bencivenga and Smith, 1991; Xu, 2000; Rioja and Valev, 2004a, 2004b; Loayza and Ranciere, 2006; Jedidia et al. 2014; Cojocaru et al. 2016, and Durusu-Ciftci, 2017).

However, some recent studies find that financial development adversely affects the economic growth (Easterly et al., 2001; Rousseau and Wachtel, 2002, 2011; Deidda and Fattouh, 2002; Loayza and Ranciere, 2006; Law and Singh, 2014). The argument is that faster rate of growth in the financial sector may be detrimental to the growth of the economy as the financial sector competes for resources with the rest of the economy (Cecchetti and Kharroubi, 2012; crowding out controversy). Rapid growth of credit along with a lack of regulatory control and monitoring from the bankers, inappropriate selection of projects, and weakening of the banking system due to non-performing assets (NPA), could have an adverse impact on economic growth. The effect of finance on growth is stronger in the case of developed countries (Demetriades and Hussein, 1996; Odedokun, 1996, and Xu, 2000). It is either weaker or inconclusive in developing countries because of less developed and inefficient financial systems with lower levels of banking intermediation (Deidda and Fattouh, 2002; Rioja and Valev, 2004a, 2004b; Kar et al., 2011). Therefore, there is a need to relook at this whole issue of how financial sector development would have an impact on economic growth in a developing country such as India.

Financial development and infrastructure development are both complementary to each other. A diversified financing mechanism is necessary for solving the funding gaps in infrastructure development. Similarly, development in infrastructure provides an easy access to financial institutions and utilise their services. Earlier studies are mostly either cross-sectional or panel of a large number of countries. Country-specific studies are very few especially in the case of India. Therefore, the objective of the study is to investigate both the short and long-run relationship between physical infrastructure, financial development and economic growth in India for the period 1980-81 to 2016-17. Based on the review, it appears that there is a dearth of studies that look at the impact of both infrastructure and financial development simultaneously on economic growth especially using recent data in the Indian context. The findings support a bi-directional causal relationship between infrastructure development and economic growth, and a uni-directional causality running from economic growth to financial development in the Indian economy. It also finds that infrastructure development has a more significant impact, and relatively plays a more crucial role than financial development on economic growth in India.

The paper is structured as follows. The analytical framework of the study is presented in section 2. The construction of the physical infrastructure index and financial development index is described in section 3. In section 4, data and econometric methodology have been discussed. Section 5 analyses the effect of physical infrastructure and financial development on economic growth, controlling other variables. Section 6 concludes the paper along with policy implication.

2. The Analytical Framework

The standard Cobb-Douglas production function states that the aggregate output of an economy for a given time depends on the labor force, capital formation, and total factor productivity, which can be presented in the following equation.

$$\boldsymbol{Y_t = AL_t^{\alpha} K_t^{\beta}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\mathbf{(1)}$$

Where,

Y_t, L_t and K_t indicate total output, labor, and capital respectively and 'A' represents the total factor productivity. The parameters, α, and β are the respective partial elasticities of labor and capital. Along with labor and capital, the study (following literature) assumes that physical infrastructure, financial development, and stable inflation could play a major role in economic growth in India. It is widely accepted that higher capital formation and employment play a crucial role in achieving economic growth and prosperity. Investment in machinery and equipment enhances total factor productivity, which promotes economic growth. Gross capital formation and growth rate of the employment in public and organized private sector are used as a proxy for capital stock and employment respectively. The role of physical infrastructure and financial development is already discussed in section 1. Thus, it includes both of these variables of interests as additional inputs in estimating the model.

It is widely believed that a mild (optimal) inflation rate accelerates economic growth by enhancing investment, creating a favourable business environment, augmenting return to savers. However, the persistence of high inflation affects the economy adversely through its various negative externalities such as the creation of uncertainty and unfavourable environment, sinking a country's international competitiveness. Inflation in India hovers at a high level during most part of the study period. Therefore, the inflation rate is used as an input in the model to measure its impact on economic growth (Mallik and Chowdhory, 2001; Faria and Carneiro, 2001; Barro, 2013).

Therefore, the present study has extended Eqn (1) as follows:

$$Y_t = AL_t^{\alpha} K_t^{\beta} Z_t^{1-\alpha-\beta} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where, Z_t includes physical infrastructure, financial development, and inflation. The linear form of the equation (2) is given in equation (3).

$$Y_t = \alpha_0 + \alpha_1 L_t + \alpha_2 K_t + \alpha_3 Z_t + \varepsilon_t \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

Based on equation (3) the estimated specifications are as follows.

LPGDP = f(LGCF, GOLAB, PINFI and INFLA) ……………...(3.1).. (Model A)
LPGDP = f(LGCF, GOLAB, FINDI and INFLA) ……………...(3.2).. (Model B)
LPGDP = f(LGCF, PINFI, FINDI and INFLA) ………………..(3.3).. (Model C)

Where,

LPGDP: Log of per capita gross domestic product; LGCF: Log of gross capital formation; GOLAB: Growth rate of employment in the public and organized private sectors;[2] PINFI: physical infrastructure index; FINDI: financial development index; and INFLA: Inflation rate.[3] The impact of physical infrastructure and other selected control variables on economic growth is examined in Model A. Then, the relationships between economic growth and financial development along with other control variables are analysed in Model B. Finally to check the robustness of the empirical estimation, Model C

2) It is found that there exists a high correlation between employment (in level) and gross capital formation (0.82), employment and physical infrastructure (0.90), and employment with financial development (0.79). Thus, to avoid multicollinearity problem, the modification of employment, i.e., the growth rate of employment, is used in the equation.
3) The details of all these variables are explained in the data section.

is estimated by incorporating both physical infrastructure and financial development along with capital and inflation in the equation. Theoretically, it is expected that the coefficients of LGCF, GOLAB, and PINFI will be positively associated with economic growth. However, FINDI and INFLA could show an ambiguous effect on growth, which needs to be analyzed in the context of India. The detailed data and the econometric methodology used in the study are described in the next section.

3. Formulation of Infrastructure and Financial Development indices using PCA

The present study has constructed two composite indices using Principal Component Analysis (PCA): physical infrastructure and financial development. The details of physical infrastructure index and financial development index are given below.

3.1: Construction of Physical Infrastructure Index

In the literature, there are various indicators that could be categorized as infrastructure. However, it is difficult to include all the infrastructure variables in the estimations (due to multicollinearity problem) but at the same time could not be left out. In this paper, a composite infrastructure index is constructed by using various physical infrastructure indicators. While constructing the infrastructure index,[4] it is found that there is a strong correlation among different infrastructure indicators (see Appendix Table 1). Therefore, to overcome the selection bias as well as multicollinearity, the paper tries to construct a physical infrastructure index (PINFI) by using the PCA. It has used three major infrastructure indicators for the PINFI and they are Total road density,[5] Electricity power consumption (kWh per capita) and Total telephone subscription per 100 people[6] in India.[7]

The construction of a PINFI requires the calculation of factor loadings of physical infrastructure indicators. Table 2 (see appendix) presents the construction of PINFI which contains eigenvalues, the variance of these factors and their respective factor loadings. It shows that the first principal component (PC1) has the largest eigenvalue and explains nearly 95 per cent of the total variance while the other two components [second principal component (PC2) and third principal component (PC3)] together explain only

4) Due to data constraints in India, the study considers only a few indicators of physical infrastructure.
5) Total road density is the ratio of the country's total road length in Km to the country's land area in Sq. Km. The road network of the country consists of National Highways, State Highways, Other Public Works Departments Roads, Rural Roads, Urban Roads and Project Roads.
6) It includes both mobile cellular subscription and fixed telephone subscription per 100 people.
7) The selected indicators are converted into standardized form before using in PCA method (due to different "unit").

five per cent of the total variance. Thus, the study has chosen PC1 to calculate the PINFI. The trend of the PINFI over 1980-81 to 2016-17 is presented in Figure 1 in the appendix.

3.2: Construction of Financial Development Index

Financial services are provided mostly by banks and other financial sector segments such as capital and money markets. However, the study has used only the bank based financial proxies for capturing financial development (FD) due to the unavailability of long time series data on other financial indicators in India (Demetriades and Luintel, 1996), such as market capitalization, turnover, and stock returns. For measuring financial development, it has used two major leading indicators of financial development suggested in the literature, i.e., money multiplier and bank credit to the commercial sector as a proportion of Gross Domestic Product (GDP). For capturing the overall size and depth of the financial sector, a normalised variable named as monetary aggregates is used in the empirical literature. The size of monetary aggregates captures many liquid liabilities of the financial system, which reflects financial deepening for providing positive financial services (King and Levine, 1993a; Demetriades and Hussein, 1996; Deidda and Fattouh, 2002). The study has used the money multiplier as one of the indicators to measure of financial development as an increase in multiplier reflects the broadening of the financial sector (see Bhavani and Bhanumurthy, 2012; Bhanumurthy and Singh, 2013). However, some studies use credit to the private sector as a proportion of GDP by arguing that monetary aggregates may not be a good proxy for financial development. It reflects only the extent of transaction services rendered by the financial system rather than the ability to channel funds from depositors to investors (Fry, 1997; Ang and McKibbin, 2007). Credit to the private sector expected to enable the allocation and utilization of funds more efficiently and productively. Thus, the study uses bank credit to the commercial sector as a proportion of GDP as an additional indicator to measure financial development (see King and Levine, 1993b; Demetriades and Hussein, 1996; Beck et al. 2000; Liang and Teng 2006; Law and Singh, 2014, and Samargandi et al., 2015). Therefore, these two major leading financial indicators provide a better picture of financial development than if we use only a single measure.

The correlation coefficient between the money multiplier and the ratio of bank credit to GDP is estimated to be as high as 0.89. Therefore, to avoid multicollinearity problem, here we construct a financial development index (FINDI) using the PCA method. Two important variables used for estimation of the index are money multiplier and the ratio of scheduled bank credit to the commercial sector to GDP. Table 3 (see appendix) presents the results of PCA (eigenvalues, respective variance, and factor loadings) for the construction of FINDI. It shows that the PC1 has an eigenvalue explaining more than 94 per cent of the total variance. Thus, the study has chosen PC1 (maximum explanatory power) to calculate the FINDI. The trend of the FINDI over 1980-81 to 2016-17 is presented in Figure 2 in the appendix.

4. Data and Methodology

4.1: The Data

The annual time series data from 1980-81 to 2016-17 are used for the empirical analysis and the following variables are used in the study. Per capita GDP at factor cost (LPGDP) is used as a proxy for economic growth. Gross capital formation (LGCF) is used as a proxy for capital in the model. Employment in the public and organized private sector (GOLAB) is used as a proxy for 'labor'.[8] PINFI is constructed by combining information derived from Total road density, Electricity power consumption and total telephone subscription (section 2.1 for detail). Similarly, FINDI is derived by using information from Money Multiplier (the ratio of Broad money to Narrow money) and bank credit to GDP ratio (see section 2.2 for detail). Inflation is calculated from GDP deflator. The summary statistics for these variables are given in Table 4 (appendix).

Data on major macro variables such as economic growth, capital stock, employment, money supply, bank credit, and inflation have been taken from the Handbook of Statistics on Indian Economy, Reserve Bank of India (RBI). Data on mobile cellular subscription and fixed telephone subscription per 100 people and Electric power consumption are taken from the World Development Indicators (WDI) database of the World Bank. Data on total road length Km has been obtained from various issues of the Basic Road Statistics of India, Ministry of Road Transport and Highways, Government of India.

4.2: ARDL Cointegration Procedure

After undertaking the unit root test (see Table 5), it is found that some variables are non-stationary at the levels but stationary in their first difference, i.e., I (1), while others do not have any unit roots, i.e., I (0). Given the mixture of I (1) and I (0) variables, and a relatively small sample size consisting of 37 annual observations, the Autoregressive Distributed Lag Model (ARDL), developed by Pesaran et al. (2001), is used here to empirically analyze the long-run dynamic relationships among the selected variables. However, this method cannot be applied to I (2) series. The following specification of the ARDL model is used in the study.

8) The annual time series employment data on the unorganized private sector is not available in India.

$$\Delta LPGDP_t = \alpha_0 + \rho T + \alpha_1 LPGDP_{t-1} + \alpha_2 LGCF_{t-1} + \alpha_3 GOLAB_{t-1} + \alpha_4 PINFI_{t-1} + \alpha_5\ INFLA_{t-1} + \sum_{i=1}^{P} \gamma_1 \Delta LPGDP_{t-i} + \sum_{i=0}^{P} \gamma_2 \Delta LGCF_{t-i} + \sum_{i=0}^{P} \gamma_3 \Delta GOLAB_{t-i} + \sum_{i=0}^{P} \gamma_4 \Delta PINFI_{t-i} + \sum_{i=0}^{P} \gamma_5 \Delta INFLA_{t-i} + \varepsilon_t \text{..........} (4)$$

$$\Delta LPGDP_t = \beta_0 + \rho T + \beta_1 LPGDP_{t-1} + \beta_2 LGCF_{t-1} + \beta_3 GOLAB_{t-1} + \beta_4 FINDI_{t-1} + \beta_5\ INFLA_{t-1} + \sum_{i=1}^{P} \phi_1 \Delta LPGDP_{t-i} + \sum_{i=0}^{P} \phi_2 \Delta LGCF_{t-i} + \sum_{i=0}^{P} \phi_3 \Delta GOLAB_{t-i} + \sum_{i=0}^{P} \phi_4 \Delta FINDI_{t-i} + \sum_{i=0}^{P} \gamma_5 \Delta INFLA_{t-i} + \mu_t \text{..........} (5)$$

$$\Delta LPGDP_t = \delta_0 + \rho T + \delta_1 LPGDP_{t-1} + \delta_2 LGCF_{t-1} + \delta_3 PINFI_{t-1} + \delta_4 FINDI_{t-1} + \delta_5\ INFLA_{t-1} + \sum_{i=1}^{P} \theta_1 \Delta LPGDP_{t-i} + \sum_{i=0}^{P} \theta_2 \Delta LGCF_{t-i} + \sum_{i=0}^{P} \theta_3 \Delta PINFI_{t-i} + \sum_{i=0}^{P} \theta_4 \Delta FINDI_{t-i} + \sum_{i=0}^{P} \theta_5 \Delta INFLA_{t-i} + \upsilon_t \text{..........} (6)$$

After estimation of equations 4 to 6, the existence of cointegration among the variables can be tested with the Wald test (*F*-statistic), which tests whether the coefficients of one period lagged levels of selected variables are jointly different from zero. The existence of a long-run relationship among the variables can be checked by testing the null hypothesis of no cointegration against its alternative hypothesis of a cointegrating relationship. The null and alternative hypotheses are as follows:

For Model A:

$H_0 : \alpha_1 = \alpha_2 = \alpha_3 = \alpha_4 = \alpha_5 = 0$ (No long-run relationship);

$H_1 : \alpha_1 \neq 0,\ \alpha_2 \neq 0, \alpha_3 \neq 0, \alpha_4 \neq 0, \alpha_5 \neq 0$ (Long-run relationship exists).

A similar test is conducted for the other two models as well.

The computed value of *F*-statistic will be compared with the critical values tabulated in Pesaran et al. (2001).[9] After the cointegration relationship is confirmed, both long-run and short-run parameters of the cointegration equations will be estimated using an appropriate lag structure.[10] The following long-run relationships (equations 7 to 9) and the corresponding error correction representation of the estimated long-run equations (equations 10 to 12) will be estimated respectively.

9) According to these authors, the lower bound critical values are based on the assumption that the explanatory variables are integrated of order zero, or I(0), while the upper bound critical values are based on an assumption that these are integrated of order one, or I(1). Therefore, if the computed *F*-statistic is smaller than the lower bound value, then the null hypothesis of no cointegration cannot be rejected. Conversely, if the computed *F*-statistic is greater than the upper bound value, then the null hypothesis of no cointegration can be rejected. On the other hand, if the computed *F*-statistic falls between the lower and upper bound values, then the results are inconclusive.

10) The orders of the ARDL models have been selected by employing the Akaike information criterion (AIC).

$$LPGDP_t = \alpha_0 + \rho T + \sum_{i=1}^{N} \alpha_1 LPGDP_{t-i} + \sum_{i=0}^{N} \alpha_2 LGCF_{t-i} + \sum_{i=0}^{N} \alpha_3 GOLAB_{t-i} + \sum_{i=0}^{N} \alpha_4 PINFI_{t-i} + \sum_{i=0}^{N} \alpha_5 INFLA_{t-i} + \varepsilon_t \quad \text{..........(7)}$$

$$LPGDP_t = \beta_0 + \rho T + \sum_{i=1}^{N} \beta_1 LPGDP_{t-i} + \sum_{i=0}^{N} \beta_2 LGCF_{t-i} + \sum_{i=0}^{N} \beta_3 GOLAB_{t-i} + \sum_{i=0}^{N} \beta_4 FINDI_{t-i} + \sum_{i=0}^{N} \beta_5 INFLA_{t-i} + \mu_t \quad \text{..........(8)}$$

$$LPGDP_t = \delta_0 + \rho T + \sum_{i=1}^{N} \delta_1 LPGDP_{t-i} + \sum_{i=0}^{N} \delta_2 LGCF_{t-i} + \sum_{i=0}^{N} \delta_3 PINFI_{t-i} + \sum_{i=0}^{N} \delta_4 FINDI_{t-i} + \sum_{i=0}^{N} \delta_5 INFLA_{t-i} + \nu_t \quad \text{..........(9)}$$

$$\Delta LPGDP_t = \alpha_0 + \sum_{i=1}^{M} \gamma_1 \Delta LPGDP_{t-i} + \sum_{i=0}^{M} \gamma_2 \Delta LGCF_{t-i} + \sum_{i=0}^{M} \gamma_3 \Delta GOLAB_{t-i} + \sum_{i=0}^{M} \gamma_4 \Delta PINFI_{t-i} + \sum_{i=0}^{M} \gamma_5 \Delta INFLA_{t-i} + \psi ECM_{t-1} + \varepsilon_t \quad \text{..........(10)}$$

$$\Delta LPGDP_t = \beta_0 + \sum_{i=1}^{M} \phi_1 \Delta LPGDP_{t-i} + \sum_{i=0}^{M} \phi_2 \Delta LGCF_{t-i} + \sum_{i=0}^{M} \phi_3 \Delta GOLAB_{t-i} + \sum_{i=0}^{M} \phi_4 \Delta PINFI_{t-i} + \sum_{i=0}^{M} \phi_5 \Delta INFLA_{t-i} + \varphi ECM_{t-1} + \mu_t \quad \text{..........(11)}$$

$$\Delta LPGDP_t = \delta_0 + \sum_{i=1}^{M} \theta_1 \Delta LPGDP_{t-i} + \sum_{i=0}^{M} \theta_2 \Delta LGCF_{t-i} + \sum_{i=0}^{M} \theta_3 \Delta PINFI_{t-i} + \sum_{i=0}^{M} \theta_4 \Delta FINDI_{t-i} + \sum_{i=0}^{M} \theta_5 \Delta INFLA_{t-i} + \Omega\, ECM_{t-1} + \nu_t \quad \text{..........(12)}$$

Where,

α_0, β_0 *and* δ_0 is an intercept, $\alpha_i, \beta_i,$ *and* δ_i are long-run coefficients, Δ is the first difference operator, $\gamma_i, \phi_i,$ *and* θ_i are short-run coefficients, ECM_{t-1} is one period lagged error correction term, ψ, φ *and* Ω the speed of adjustment, T- Trend, ε_t, μ_t *and* ν_t, is the error term of the estimated model and all other variables are defined before. The next section presents the empirical analysis of the study.

5. Empirical Analysis

5.1: Unit Root Tests

It is necessary to check stationarity tests for time series variables to avoid spuriousness before going for any estimation. The unit root tests might be necessary for the ARDL procedure to ensure that none of the variables is I (2) stationary. Both the Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) tests are used to determine the stationarity of variables. Table 5 presents the results of unit root tests (see appendix). It confirms that some variables like LPGDP, LGCF, PINFI, FINDI, and INFLA are integrated of order one, i.e., I (1), while the variable, i.e., GOLAB is integrated of order zero, i.e., I (0). It indicates none of the selected variables is I (2). Thus, the ARDL approach is a more appropriate method for empirical analysis.

5.2: Bounds Testing Approach to Cointegration

The ARDL bounds testing approach to cointegration have been performed to confirm the long-run relationships among the selected variables. The initial step in the ARDL bounds testing approach is to estimate an Ordinary Least Square (OLS) regression for the first difference of both dependent and independent variables. Then, the joint significance of the parameters of the lagged level variables added to the regression is tested by using a Wald test (F-statistic). The F-statistic tests the joint null hypothesis that the coefficients of the lagged level variables are zero (i.e., no long-run relationship) against its alternative of long-run relationship. Table 6 displays the results of the bounds test of the selected ARDL models.

The computed value of F-statistics for Model A and Model C are 6.14 and 9.45 respectively, which is higher than the upper bound critical value (5.72) at one per cent significance level. Accordingly, the null hypothesis of no co-integration is rejected in favour of the alternative at one per cent level of significance. Similarly, the null of no cointegration is rejected for Model B, as the computed F-statistic (5.70) is higher than the upper bound critical value (4.57) at five per cent level of significance. Hence, the bounds test confirms the long-run relationship between the selected variables.

Table 6: Results of the ARDL Bound Test

ARDL Model					**F-Stat.**
Mod. A	LPGDP= f(LGCF, GOLAB, PINFI, INFLA)				6.144***
Mod. B	LPGDP= f(LGCF, GOLAB, FINDI, INFLA)				5.70**
Mod. C	LPGDP= f(LGCF, PINFI, FINDI, INFLA)				9.446***
Critical Value Bounds of the F-Statistic at 10, 5 and 1 per cent levels					
10 per cent		**5 per cent**		**1 per cent**	
I(0)	**I(1)**	**I(0)**	**I(1)**	**I(0)**	**I(1)**
3.03	4.06	3.47	4.57	4.40	5.72

Note: Case 5: Unrestricted Constant and Unrestricted Trend, critical values for the bounds test by Pesaran et al. (2001). *** and ** denote 1% and 5% level of significance respectively.

5.3: Estimated Long-run and Short-run Coefficients using the ARDL Approach

After confirmation of the long-run relationship among these variables, equation 7 to 9 is estimated. The lag selections of these models are carried out using the Akaike information criterion (AIC). The results of both long-run and short-run estimations are reported in Table 7.

Table 7: Estimation of Long-run and Short-run Coefficients

	Long-run Coeff				**Short-run Coeff**		
	Model A	Model B	Model C		Model A	Model B	Model C
Variable	Coeff	Coeff	Coeff	**Variable**	Coeff	Coeff	Coeff
LGCF	0.156*** (2.902)	0.124* (1.775)	0.074* (1.845)	**ΔLPGDP**	-	-	0.519** (2.570)
GOLAB	0.034*** (3.380)	0.045*** (4.366)	-	**ΔLGCF**	0.096** (2.681)	0.067** (2.129)	0.072** (2.348)
PINFI	0.051*** (3.674)	-	0.075*** (11.845)	**ΔGOLAB**	0.006 (1.616)	0.005 (1.317)	-
FINDI	-	0.039* (1.812)	0.038*** (3.191)	**ΔPINFI**	0.072* (1.766)	-	0.127*** (3.686)
INFLA	-0.013*** (-3.833)	-0.015*** (-3.382)	- 0.007*** (-4.275)	**ΔFINDI**	-	-0.011 (0.499)	-0.017 (-1.493)
C	8.093*** (23.378)	8.212*** (16.962)	9.009*** (29.536)	**ΔINFLA**	-0.005** (-2.438)	-0.005*** (-3.137)	-0.006*** (-4.30)
TREND	0.023*** (4.70)	0.031*** (6.976)	0.020*** (10.023)	**C**	0.014*** (3.445)	0.017*** (3.078)	0.019*** (3.453)
				$ECMT_{t-1}$	-0.618*** (-4.694)	-0.542*** (-4.105)	-0.967*** (-4.223)

Diagnostic Tests	**Model A**	**Model B**	**Model C**
Serial Correlation Test:	0.262 [0.772]	0.890 [0.427]	2.099 [0.122]
Normality Test:	0.682 [0.711]	1.745 [0.418]	1.575 [0.455]
Hetero-Scedasticity Test:	1.352 [0.263]	1.016 [0.469]	0.894 [0.567]
ARCH Test:	1.849 [0.184]	0.244 [0.625]	1.125 [0.297]
Ramsey RESET Test:	0.495 [0.490]	0.574 [0.457]	0.289 [0.597]

Note: ***, ** and * denotes 1, 5 and 10 per cent levels of significance respectively. Coeff is estimated Coefficients. The figures in brackets ( ) and [ ] are the t-statistics and the P-values respectively. For Model A, ARDL (1, 0, 2, 3, 1) selected based on AIC. Model B, ARDL (1, 0, 2, 3, 1) selected based on AIC. Model C, ARDL (4, 0, 1, 2, 0) selected based on AIC.

The estimation of long-run coefficients by ARDL method reveals that the impact of infrastructure development (PINFI) on economic growth is positive and highly significant at one per cent level. Based on the estimation of Model A to C, it finds that one unit rise in PINFI raises economic growth by 5 to 7.5 per cent. It implies that in the long-run, physical infrastructure development plays a crucial role in influencing economic growth in India. Thus, physical infrastructure, like roads, power supply, and telecommunication lines should be provided to bolster growth in the economy.[11] Similarly, financial development also found to have a significant positive impact on economic growth (model B and C). The

11) The estimated coefficients of these variables are calculated in section 5.4.

results show that one unit increase in financial development leads to nearly 4 per cent increase in economic growth in the long-run. Thus, the magnitude of the long-run coefficients of infrastructure development is higher than the coefficients of financial development imply that infrastructure development has a larger impact than financial development on economic growth in India.

As expected, the estimated coefficient of LGCF (hereafter gross investment) and GOLAB (employment) have positive and significant effects on economic growth in all the models. Thus, India should focus on more investment and create more organized employment for enhancing economic growth in India. However, inflation has an adverse effect on economic growth in all these models and also highly statistically significant at one per cent level. It implies that high inflation is not desirable for India in the long-run. The recent monetary policy framework in India that has flexible inflation targeting, if successful, might be a major source of growth in the country in the coming years.

The results of the short-run estimates show that the speed of adjustment terms in all these models are very high and highly significant at one per cent level. Thus, it confirms long-run relationships and causality among the selected variables. In the short-run, it finds that both infrastructure development and gross investment have a positive and significant effect on economic growth, while financial development and employment have an insignificant impact on economic growth. Therefore, the favourable impacts of infrastructure and gross investment on economic growth are immediately realized in India compared to financial sector development. It also finds that inflation has a negative and significant impact on economic growth in the short-run.

The robustness of the estimated model has been tested by several diagnostic checks such as Serial Correlation Test, Jacque-Bera Normality Test, Heteroscedasticity Test, ARCH Test and Ramsey RESET specification test. The results of diagnostic tests (lower part of Table 7) show that the selected models have no serial correlation, no heteroscedasticity, normally distributed and well specified. The results of the stability tests, i.e., the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUM SQ) are plotted in figure 3 to 5 (appendix). It shows that neither the CUSUM nor the CUSUM square test statistics exceed the bounds of 5 per cent levels of significance, which confirms the estimated model is stable over time. Hence, the results from these models are robust and reliable.

Thus, it finds that physical infrastructure has a positive effect on economic growth both in the long-run and short-run, whereas financial development has a favourable impact on economic growth only in the long-run. Our results support that physical infrastructure relatively plays a more crucial role than financial development for boosting up economic growth in India. In the next section, the long-run coefficient of both physical infrastructure and financial development is calculated.

5.4: Deriving the Coefficients of Constructed Indices

As discussed earlier (section 2.1) PINFI is mainly constructed by using three leading indicators of physical infrastructure, i.e., total road density, telephone subscription, and electricity power consumption. Considering the importance of different types of physical infrastructures, it has calculated the long-run coefficients of individual infrastructure indicators by multiplying the estimated coefficient of the PINFI (from ARDL models) with the factor loading (from PCA) of the individual infrastructure indicator. Similarly, FINDI index has used two crucial financial variables, i.e., money multiplier and the ratio of scheduled bank credit to the commercial sector to GDP. The similar method is applied to get the long-run coefficients of individual financial indicators, i.e., by multiplying the estimated long-run coefficients with the factor loadings. The estimated coefficients are shown in Table 8.

Table 8: Long-run Coefficients of Selected Infrastructure and Financial Indicators

Infrastructure Development Indicators			**Financial Development Indicators**		
Variables	Coefficients (Model A)	Coefficients (Model C)	Variables	Coefficients (Model B)	Coefficients (Model C)
Road density	0.030	0.044	Money Multiplier	0.028	0.027
Telephone Subscription	0.029	0.042	Bank Credit to GDP	0.028	0.027
Electric power consumption	0.030	0.044			

From the ARDL model estimation, it finds that the long-run coefficient of PINFI is 0.051 and 0.075 for model A and model C respectively. The long-run coefficient of finance development index is 0.039 and 0.038 for model B and C respectively. Then, both the long-run coefficient of PINFI is multiplied with the factor loadings (0.58, 0.56 and 0.59 respectively) of all these infrastructure indicators and FINDI is multiplied with the factor loadings of 0.71 each as given in Table 8. The results find that one unit change in Road density, Telephone subscription, and Electric power consumption enhances economic growth by 3 to 4.5 per cent. Among physical infrastructure, electricity and road construction has a more significant impact than communication. The results also show that one unit change in financial indicators leads to 2.7 to 2.8 per cent increase in economic growth. Thus, the extraction of long-run coefficient also confirms that physical infrastructure plays a more crucial role than financial development for accelerating economic growth in India.

5.5: Testing Casual Relationship between Economic Growth, Infrastructure and Financial Development

The long-run relationship is ensured by the ARDL bounds testing approach. Thus, it would be very important to know the direction of the causal relationship between the variables of interest, i.e., whether it is unidirectional or bidirectional. Therefore, a modified version of the Granger causality test proposed by Toda and Yamamoto (1995) is applied to examine the direction of the causal relationship between Economic Growth, Infrastructure and Financial Development. The advantage of this test is that it can be applied to all series, i.e., I (0), I (1) or I (2), and whether these series are cointegrated or not-cointegrated. This approach fits a standard vector autoregressive (VAR) model in the levels of the variables, irrespective of their level of integration. Thus, the risk associated with the possibility of wrongly identifying the integration order of the series is minimized. The first step is that the order of integration ($d_{\max}$) of the series under consideration and the optimal lag, k has to be determined. Then a (k+$d_{\max}$) order of VAR is estimated, and the coefficients of the last lagged $d_{\max}$ vector are ignored. The application of the Toda and Yamamoto (1995) procedure ensures that the usual test statistic for Granger causality has the standard asymptotic distribution, where valid inference can be made.

The Toda and Yamamoto (1995) approach are carried out in the following VAR system:

Between Economic Growth and Physical Infrastructure

$$PGDP_t = \alpha_0 + \sum_{i=1}^{k} \alpha_1 PGDP_{t-i} + \sum_{i=k+1}^{d_{\max}} \alpha_2 PGDP_{t-i} + \sum_{i=1}^{k} \Phi_1 PINFI_{t-i} + \sum_{i=k+1}^{d_{\max}} \Phi_2 PINFI_{t-i} + \lambda_{1t} --- eq(13)$$

$$PINFI_t = \beta_0 + \sum_{i=1}^{k} \beta_1 PINFI_{t-i} + \sum_{i=k+1}^{d_{\max}} \beta_2 PINFI_{t-i} + \sum_{i=1}^{k} \delta_1 PGDP_{t-i} + \sum_{i=k+1}^{d_{\max}} \delta_2 PGDP_{t-i} + \lambda_{2t} --- eq(14)$$

Between Economic Growth and Financial Development

$$PGDP_t = \alpha_0 + \sum_{i=1}^{k} \alpha_1 PGDP_{t-i} + \sum_{i=k+1}^{d_{\max}} \alpha_2 PGDP_{t-i} + \sum_{i=1}^{k} \Phi_1 FINDI_{t-i} + \sum_{i=k+1}^{d_{\max}} \Phi_2 FINDI_{t-i} + \lambda_{1t} --- eq(15)$$

$$FINDI_t = \beta_0 + \sum_{i=1}^{k} \beta_1 FINDI_{t-i} + \sum_{i=k+1}^{d_{\max}} \beta_2 FINDI_{t-i} + \sum_{i=1}^{k} \delta_1 PGDP_{t-i} + \sum_{i=k+1}^{d_{\max}} \delta_2 PGDP_{t-i} + \lambda_{2t} --- eq(16)$$

Where,

PGDP: per capita GDP; PINFI: Physical infrastructure index and FINDI: Financial Development Index. From Eq. (13), the causal relationship from $PINFI_t$ to $PGDP_t$ implies $\Phi_{1i} = 0 \forall_i$; similarly in eq. (14), $PGDP_t$ does granger causes $PINFI_t$, if $\delta_{1i} = 0 \forall_i$. A similar kind of analysis is also followed to check the causal relationship between economic growth and financial development index. Thus, to experiment the above equations (13) and (14) is modified by replacing the variable FINDI in the place of the variable PINFI. Results of the causality tests are presented in Table 9 by using Akaike Information Criteria (AIC) and Schwarz information criterion (SBC) to select the optimal lag.

The results show that the hypotheses of infrastructure development do not Granger cause economic growth is rejected at five per cent level of significance [eq. (13)]. Similarly, economic growth does not Granger cause infrastructure development is also rejected by the applied causality test [eq. (14)]. Therefore, a bi-directional causality is found between economic growth and infrastructure development. However, while testing causality between economic growth and financial development, it finds that causality runs one-way from economic growth to financial development. Because the hypotheses of financial development do not Granger cause economic growth is not rejected [eq. (15)]. Here, there is a unidirectional causality runs from economic growth to financial development. The similar kind of causality analysis between financial development and infrastructure development shows that causality runs one-way from infrastructure development to finance development.[12] It indicates that financial development occurs due to demand-side factors in India. Overall, the empirical results support that infrastructure development has a substantial impact on economic growth while financial development has a relatively weak effect on economic growth in India.

Table 9: The results of the Toda–Yamamoto approach to Granger causality test

Variables	Statistics(Chi-sq)	Direction of causality
PINFI does not Granger Cause PGDP	7.981** (0.046)	Bidirectional (PINFI↔PGDP)
PGDP does not Granger Cause PINFI	10.674** (0.014)	
FINDI does not Granger Cause PGDP	1.291 (0.524)	Unidirectional (PGDP→FINDI)
PGDP does not Granger Cause FINDI	7.544** (0.023)	

Note: ** denotes Significant levels at 5%. The figures in parentheses are the P-values.

6. Conclusion

The paper examines the role of physical infrastructure and financial development in economic growth in India for the period from 1980-81 to 2016-17. For this purpose,

12) The results are with authors and can be available upon request.

two composite indices have been estimated by using PCA, i.e., physical infrastructure index and financial development index. Three major infrastructure indicators such as total road density, electricity power consumption, and total telephone subscription are used for the construction of physical infrastructure index. Similarly, financial development index is prepared by using two major financial indicators, i.e., money multiplier and the ratio of scheduled bank credit to the commercial sector to GDP. The long-run and the short-run relationship among the selected variables are verified by using the ARDL approach. The ARDL bounds test results support the long-run relationship among the selected variables.

The empirical results of the present study reveal that the physical infrastructure has a significant and favorable impact on economic growth both in the long-run and short-run. Similarly, financial development also has a significant positive impact on economic growth in the long-run but an insignificant impact on economic growth in the short-run. Among physical infrastructure, electricity and road construction has a more significant impact than communication. The long-run results demonstrate that infrastructure development relatively plays a more crucial role than financial development on economic growth in India. The Toda-Yamamoto modified causality test supports a bi-directional causal relationship between infrastructure development and economic growth, while it finds a unidirectional causality running from economic growth to financial development. Overall, the empirical results support that infrastructure development has a substantial impact on economic growth while financial development has a relatively weak effect on economic growth in India. Rather it is the economic growth that is helping the expansion of the financial sector in India from the demand side.

Gross investment and employment have a significant and positive effect on economic growth, while inflation has a negative effect on economic growth in India. Thus, greater emphasis should be given for infrastructure development to achieve sustained high economic growth in India. The study can be extended by examining the role of both private investment and public investment (disaggregating gross investment) in economic growth. From the results, it suggests that the transmission channel is from infrastructure growth to output growth and then to the development of the financial sector. Therefore, our findings support the argument in favour of economic growth leading to financial development rather than financial development leads to economic growth in the Indian context. Recently, India has been facing a twin balance sheet problem. Therefore, private sector participation in infrastructure development is rather limited. Thus, to achieve high and sustainable growth, there is a need for Government intervention in expanding the physical infrastructure and financial development in the country.

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Appendix

Table 1: Co-relationship between selected infrastructure indicators

Infrastructure Variables	Road Density	Telephone Subscription	Electricity Consumption
Road Density	1		
Telephone Subscription	0.86	1	
Electricity Consumption	0.99	0.92	1

Table 2: Construction of the Physical Infrastructure Index

Principal Components	Eigen Values	% Variation	% cumulative
PC1	2.85	95.04	95.04
PC2	0.15	4.86	99.90
PC3	0.00	0.1	100.00
Eigen Vectors (Factor Loadings)			
Infrastru. variables	**PC 1**	**PC 2**	**PC 3**
Road density	0.58	-0.56	0.59
Telephone subscription	0.56	0.80	0.21
Electricity consumption	0.59	-0.22	-0.78

Table 3: Construction of the Financial Development Index

Principal Components	Eigen Values	% Variation	% cumulative
PC1	1.89	94.36	94.36
PC2	0.11	5.64	100.00
Eigen Vectors (Factor Loadings)			
Financial Development	**PC 1**	**PC 2**	
Money Multiplier	0.71	-0.71	
Bank Credit	0.71	0.71	

Table 4: Summary Statistics of the Variables

Statistics	LGDP	LGCF	GOLAB	PINFI	FINDI	INFLA
Maximum	10.91	10.04	4.06	3.82	3.04	13.74
Minimum	9.37	7.36	-2.12	-2.00	-1.57	1.00
Mean	10.03	8.76	0.92	0.00	0.00	7.16
Std. Dev.	0.47	0.85	1.23	1.71	1.39	2.81
Skewness	0.35	0.18	-0.33	0.84	0.61	-0.14
Kurtosis	1.84	1.67	3.82	2.54	1.90	2.65
Observations	37	37	37	37	37	37

Table 5: Results of Unit Root Test

	ADF Test		PP Test		
Variables	Level	First Difference	Level	First Difference	Decision
LPGDP	-1.19 (0.90)	-5.13*** (0.00)	-1.19 (0.90)	-5.08*** (0.00)	I(1)
LGCF	-2.14 (0.51)	-7.60*** (0.00)	-2.13 (0.51)	-7.60*** (0.00)	I(1)
GOLAB	-3.22** (0.03)	-9.56*** (0.00)	-3.19** (0.03)	-9.78*** (0.00)	I(0)
PINFI	-0.43 (0.98)	-5.69*** (0.00)	-0.09 (0.99)	-5.71*** (0.00)	I(1)
FINDI	-0.96 (0.94)	-5.35*** (0.00)	-0.65 (0.97)	-5.12*** (0.00)	I(1)
INFLA	-2.79 (0.21)	-7.76*** (0.00)	-2.88 (0.18)	-7.74*** (0.00)	I(1)

Note: ***, ** and * denotes 1, 5 and 10 per cent levels of significance respectively. The figures in ( ) are P-values.

Figure 1: Trend of Physical Infrastructure Index

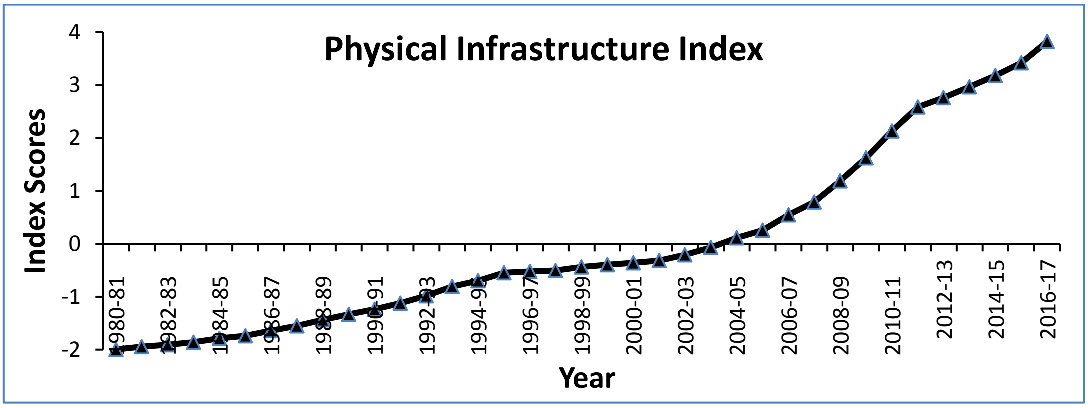


Fig 2: Trend of Financial Development Index

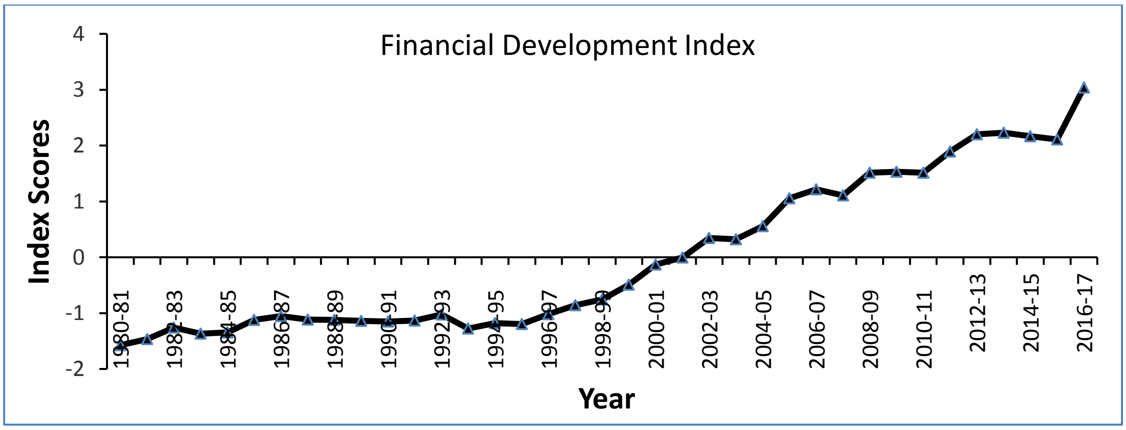


Figure 3: CUSUM and CUSUMQ Tests of the Model A

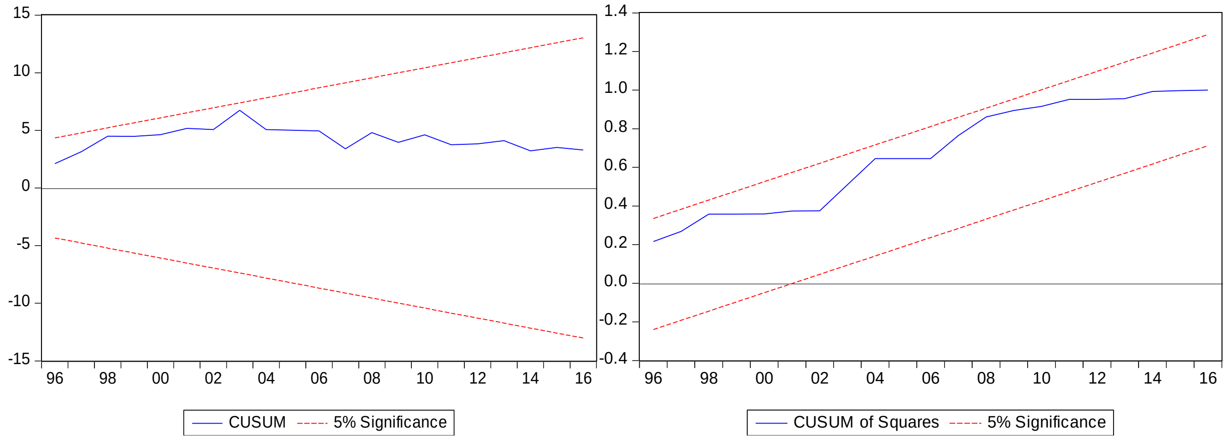


Figure 4: CUSUM and CUSUMQ Tests of the Model B

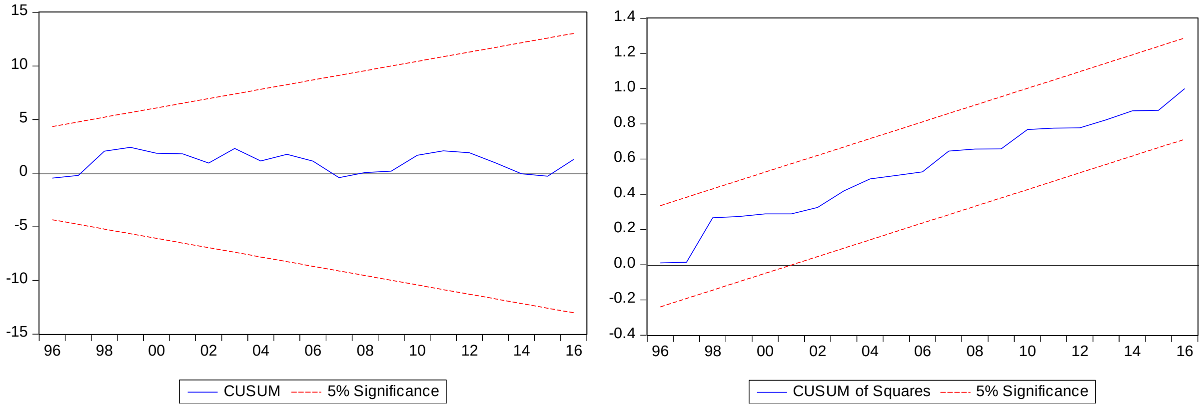
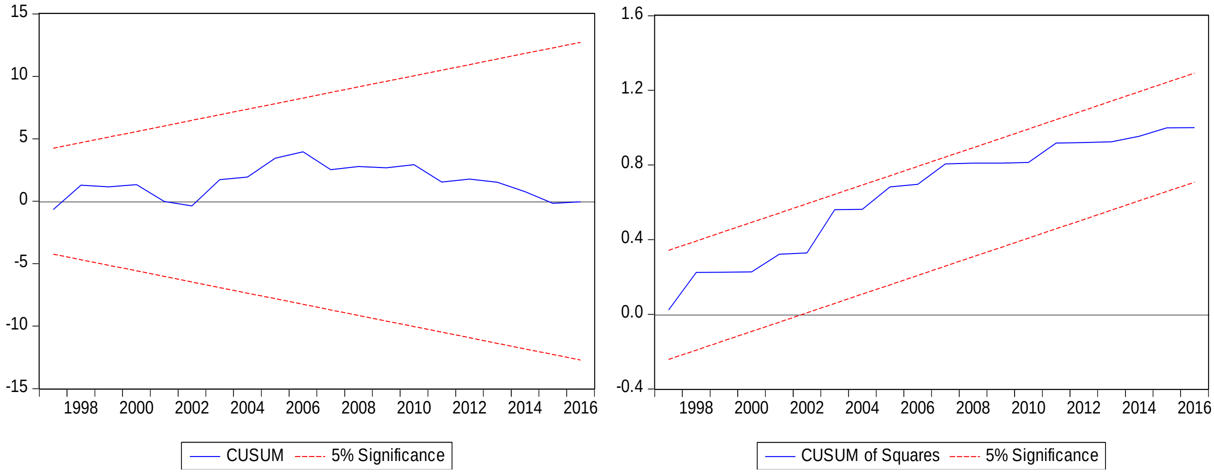


Figure 5: CUSUM and CUSUMQ Tests of the Model C



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Ranjan Kumar Mohanty, is Economist, NIPFP
Email: ranjan.mohanty@nipfp.org.in

N. R. Bhanumurthy, is Professor, NIPFP
Email: nr.bhanumurthy@nipfp.org.in

National Institute of Public Finance and Policy,
18/2, Satsang Vihar Marg,
Special Institutional Area (Near JNU),
New Delhi 110067
Tel. No. 26569303, 26569780, 26569784
Fax: 91-11-26852548
www.nipfp.org.in