

Economic Infrastructure and Long Run Economic Growth in Pakistan: A New Insight

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Abstracts
The role of economic infrastructure in economic growth and development is given substantial importance in theoretical and empirical literature. In this study, economic infrastructure is disaggregated into transport, communication and power to study its effect on long run economic growth over the period 1971-2014 using Autoregressive Distributed Lag (ARDL) method. In this study we examine the impact of each component of economic infrastructure on long run economic growth and then analyze the impact of sub-indices of transportation and energy, and composite economic infrastructure index on GDP per capita. Results suggest that high roads have negative impact on per capita GDP due to over investment in high roads. However private investment, energy consumption and electricity consumption positively and significantly impact per capita GDP. Generally transport index, energy index and composite economic infrastructure index has positive effect on GDP per capita.
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1. Introduction

Infrastructure affects economic growth and productivity. Directly it contributes in the formation of GDP and as an additional factor input in the production process of other sectors. Indirectly it raises the total factor productivity by reducing trade and transaction cost that enhances growth. Investment in infrastructure not only facilitates production process but it also enhances economic activities, create employment opportunities to the poor and connecting markets (Sahoo *et al*., 2010). A number of studies in literature have found high returns to the investment in infrastructure that impact productivity in a positive way (Aschauer, 1989a, b, Fernald, 1999, Canning and Pedroni, 2008, Calderon et al, 2011). Most studies of the economic growth document the role of economic infrastructure and find significant positive impact of infrastructure on output, productivity and long run growth.
The role of economic infrastructure in economic growth has drawn the attention of policy makers, researchers and economists since the work of Aschauer (1988, 1989). He emphasizes that the growth rate of United States declines due to cut down of public expenditures on infrastructure, however the magnitude of the effect of public capital is controversial in literature. Barro (1990) takes constant return to scale model of endogenous growth and incorporate public capital in it by emphasizing that privately determined saving and growth rates are suboptimal but transitional dynamics are ignored. Later on Futagami *et al.* (1993) develop an sophisticated model by taking private and public capital in framework of endogenous growth model to study their transitional dynamics.

Economic infrastructure such as highways, airports, telephone lines, electricity consumption and energy consumption equivalent to oil consumption are stock in nature (Futagami *et al*., 1993). There are several studies that support the importance of economic infrastructure in private production. For instance economic infrastructure raises the marginal productivity of private capital that has positive effect on output (Aschauer, 1988). However Devarajan *et al*. (1996) and Ghani and Din (2006) found negative and insignificant impact of public investment on economic growth that has raised some concern about the efficiency of public investment. Strand of growth literature emphasizes that it is necessary for developing and emerging economies to make investment in infrastructure to accelerate economic growth.

We disaggregate economic infrastructure into transportation, communication and power. These are the essential components for the functioning of modern economy and focus of this paper. Transport infrastructure is considered as key to promoting growth and development through market access for the sale of goods and services and mobility of labor from rural to urban areas to find suitable jobs (Banerjee et al, 2012). We support this argument by taking the historical example of construction of railroad infrastructure that led to rapid economic growth in Western Europe, Japan and United States (Banerjee et al., 2012). Similarly, well-developed communication system allows dissemination of information and ideas freely that enables business men to take decision in timely manners that enhance economic efficiency. Economic activities also depend on uninterrupted flow of electricity supply; therefore industries can work efficiently without any hazard (Global Competitive Report, 2014-15). In principle, economic infrastructure raises the marginal productivity of physical capital and other types of capital that spur long run economic growth.

Countries that invest in economic infrastructure (such as utilities) are in a better position to attract foreign

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direct investment and tourism that spur commerce and support local businesses. China, Taiwan and Korea made tremendous success in their own infrastructure establishment. In case of Pakistan, there is a frequent cutback in the Public Sector Development Program (PSDP) that report low level of allocation, so there is need to enhance the infrastructures investment that is essential ingredients of economic growth. Investment in infrastructure has a declining trend aggravating the situation in Pakistan (Imran and Niazi, 2011). In addition, the energy crisis has affected Pakistan's economy badly and suppressed the growth. Recently, infrastructure development and its impact on productivity are the issues in the discourse on the public policies in Pakistan and it is also the part of vision 2025 of the country. Low investment in infrastructure not only acts as binding constraints on the production sector of economy but it also deteriorates the wellbeing of society. According to the Global Competitive Report 2013-2014, "Pakistan's infrastructure remains at dire state particularly, electricity crisis squeeze overall economy". We display the position of infrastructure in term of cross countries infrastructure ranking. Table 1 shows that the economic infrastructure of Pakistan is underdeveloped. In 2014-2015, it has been ranked 113th while in term of quality of electricity supply, it is ranked 133rd. This portrays the situation of severe electricity crisis in Pakistan. However, Pakistan's performance is slightly good in railroad, air aviation and port infrastructure. It is further mentioned that 80% of SMEs were not able to take in new investment over the years due to insufficient supply of electricity (ADB, 2008).

Table 1: Global Competitiveness Index of Pakistan

Economic Infrastructure	2011-2012	2012-2013	2013-2014	2014-2015
Quality of economic infrastructure	109	105	119	113
Quality of roads	79	73	72	75
Quality of railroad infrastructure	59	66	75	72
Quality of port infrastructure	72	60	55	59
Quality of air transport infrastructure	85	78	88	92
Available airline seat km/week, millions	48	49	46	48
Quality of electricity supply	126	126	135	133
Mobile telephone subscriptions/100 pop	120	122	125	124
9 Fixed telephone lines/100 pop	119	113	115	111

Source: Global Competitiveness Report

A further analysis is required to understand the effects of economic infrastructure on economic growth. Therefore the objective of this paper is to examine the impact of economic infrastructure on long run economic growth of Pakistan. In case of Pakistan, such type of study has not been done yet that have studied the impact of economic infrastructure on long run economic growth. To this end, we contribute in the literature by analyzing the impact of different types of economic infrastructure on long run economic growth of Pakistan in this paper. The economic infrastructures whose separate effects are examined include; high roads, railroads, air transport, fixed telephone subscription, electricity consumption and energy consumption equivalent to oil consumption. These indicators capture different dimension of economic infrastructure such as transportation, communication and power.

This empirical analysis uses the time series data of Pakistan over the period 1971-2014. Due to small sample size, we use Autoregressive distributed lagged (ARDL) technique to determine the long run and short run relationship between economic infrastructure and economic growth. To tackle the problem of reverse causation, we use Vector Error Correction Model approach to find out the direction of causality.

This paper is organized as; Second section discusses relevant theoretical and empirical literature on infrastructure development and economic growth. Section three presents theoretical framework of infrastructure development and economic growth. Section four is about Methodology and Data. Section five presents Results. Section six concludes overall findings of the study and suggests some policy implications.

2. Literature Review

Arrow and Kuz (1970) develop theoretical model where consumers derive utility from private capital and public capital stock. They find that government investments have positive impact on productivity and enhance the marginal productivity of private capital. Although, Arrow and Kuz use exogenous growth model in which public capital affects transitional growth rate and have no impact on long run growth rate. Aschauer (1989) considers that government expenditures are productive and increase in expenditures beyond some extent increases aggregate demand, interest rate and productivity. Furthermore Aschauer finds that government expenditures on core infrastructure such as roads, highways, sewage, airport and water system have positive effect on long run productivity and economic growth whereas military expenditures have little relation with productivity in US. Aschauer (1989) and Barro (1990) introduce conventional channel, in which infrastructure raises the marginal productivity of private capital. Productivity growth slows down in 1970s in US due to lack of investment in infrastructure (Aschauer, 1989). His major findings are that the output elasticity of public capital in the US is 0.39 while 80% decline in productivity growth during 1970's is due to decline in growth of public investment. Therefore we get insight from their studies that government investment in infrastructure raises the marginal productivity of all factor inputs but at diminishing rate. It is known as standard accelerator effect in which scale effects in production leads to more private investment that increases the production capacity over time. Therefore persistent long run growth is achieved (Agenor and Moreno-Dodson, 2006).

Canning and Pedroni (2004) analyze the impact of stock of infrastructure on the long run economic growth. They incorporate infrastructure as input factor in production function by following Barro's public spending model. When a country has infrastructure below its maximizing level, then shock to infrastructure has positive effect on output. However if infrastructure lies above optimal level, then infrastructure shock has negative effect on output level. They use balanced panel data over the period 1950-1992 and encounter the problem of unit root in their variables. All variables are not stationary at level; therefore, Pedroni cointegration test is used to assess short run and long run relation between infrastructure and economic growth. They find the presence of long run relationship between infrastructure and economic growth. Their results also show that paved roads, electricity generating capacity and communication are provided in given countries but in some countries are under supplied and in some are over supplied. This is the main reason why time series and panel data results are contradictory.

Later on Agenor and Moreno Dodson (2006) examine that increase in public investment on infrastructure has positive effect on the marginal productivity of other factors. In principal public investment works as accelerator in the process of private investment. Public investment in infrastructure and private investment have scale effects that lead to persistent growth and productivity in long run. However, they discuss the other channel through which an increase in public capital stock crowds out private investment in short run. The negative crowding out effect might have negative effects on productivity and growth if private investment declines persistently in long run.

Most of the empirical studies find positive relationship between infrastructure development, productivity and economic growth. But the results depend on which proxy they use for infrastructure development. Such as Straub (2008) uses physical infrastructure as an indicator for infrastructure development and observes positive effect of it on economic growth. Supply of infrastructure is key determinant of development. But lack of infrastructure capital is the bottleneck in the process of growth and development in panel of Sub-Saharan African countries (Calderon and Serven, 2008). To fix the problems of endogeneity and reverse causality, they use generalized method of moment (GMM) and use the lagged value of regressors as instruments. However, quantity synthetic index as well as quality synthetic infrastructure index has positive impact on economic growth.

A study on India finds that infrastructure development has significant positive impact on economic growth of India during the period 1970-2006 (Sahoo and Dash, 2009). However, this study does not consider the problem of endogeneity. The estimators obtained may be inconsistent. Furthermore another empirical study reveals that infrastructure indices such as transportation index, communication index, electricity index and composite communication have positively and significantly contributing in GDP per capita growth in Egypt. Increases in infrastructure expenditures have positive impact on infrastructure development (Loayza and Odawara, 2010). Similar study for South Asian countries has been carried out using panel cointegration technique of Pedroni to examine the long run relationship between infrastructure and economic growth. Economic and social infrastructures contribute positively to economic growth (Sahoo and Dash, 2014).

In case of Pakistan, limited literature is available on infrastructure and economic growth. However Hyder (2001) investigates the impact of public investment on private investment and growth using Vector Autoregressive (VAR) method for the time period 1964 to 2001. He finds the complementary relationship between public and private investments and both types of investment affect economic growth positively. Few studies so far done indicate that either aggregate public investment has insignificant or negative effect on growth (Ghani and Din, 2006; Rehman, Iqbal and Saddique, 2010).

More recently, Vaqar *et al*. (2013) use dynamic CGE model to analyze the impact of public infrastructure investment finance through internal source and external source on economic growth. They find that when investment in infrastructure is financed through internal sources, then it puts a constraint on the output of industrial sector, so it reduces economic growth in short run. However, when infrastructure investment is financed through international borrowing, then it leads to decline exports in the first year of investment. Another study of Imran and Niazi (2013) examine the impact of infrastructure on total factor productivity and economic growth. Underinvestment in infrastructure has adverse effect on TFP and economic growth. They emphasize that Pakistan government should divert resource away from communication sector to water and power to boost up economic growth. Ahmed and Ali (2016) analyze the impact of public investment on output, private investment and employment using vector Autoregressive (VAR) method. Disaggregated data of nine sectors of economy of Pakistan has been used over the period 1964 to 2014. They find that the public investment and social investment impact output and both have crowding in effects on private investment in 49 cases. In the light of studies cited above, there is need to investigate impact of each component of economic infrastructure on long run economic growth of Pakistan.

3. Theoretical Framework

We assume that investment in economic infrastructure has positive impact on private production and this stems from the fact that roads, highways, airports, electricity and gas utilities enhance the marginal productivity of private capital formation (Aschauer, 1988). Indirectly it raises the total factor productivity that has positive impact on output or economic growth. Output produced is the function of labor and economic infrastructure capital that consists of transport, communication and power. Following Mankiw, Romer and Weil (1992), we assume the Cobb Dauglas production function and it is specified as

$$Y_t = A_t L_t^{1-\sum_{i=1}^{3}\beta_i} K_t^{\beta_1} K_c^{\beta_2} K_{en}^{\beta_3} \ldots\ldots\ldots (1)$$

Y is the aggregate output produced at time t; L is the aggregate hours supplied by labor; A is the efficiency enhancing parameter; K_t represents transport infrastructure; K_c is the communication infrastructure and K_e is the power infrastructure; β_i represents share of respective factor input i in production of Y_t and labor grows exogenously at the n due to population growth. It is assumed that constant amount of saving s_i is invested in each type of infrastructure. Output per unit of effective labor can be written as

$$y_t = A_t {k_i}^{\beta_i} \ldots\ldots\ldots (2)$$

For infrastructure per unit of effective labor and output per unit of effective labor, we define the following differential equation that governs changes in the accumulation of the k_i

$$\dot{k}_i = s_i A {k_i}^{\beta_i} - (n + \delta_i) k_i \ldots\ldots\ldots (3)$$

In equation (2), δ_i shows the depreciation of each type of infrastructure. In steady state $\dot{k}_i = 0$ for each type of infrastructure. Therefore, we get the following value of each type of infrastructure

$$k_i^* = \left[\frac{As_i}{n+\delta}\right]^{1/1-\beta_i}$$

By substituting k_i^* in equation (2), we get the following expression

$$y^* = A\left[\frac{As_i}{n+\delta}\right]^{\beta_i/1-\beta_i} \ldots\ldots\ldots (4)$$

Taking the natural log on the both side of equation (4), we obtain

$$ln(y^*) = \frac{lnA}{1-\beta_i} + \frac{\beta_i}{1-\beta_i} lns_i - \frac{\beta_i}{1-\beta_i}\ln(n+\delta) \ldots\ldots\ldots (5)$$

Let assume that $\frac{lnA}{1-\beta_i} = \beta_\circ$. We assume that the rate of depreciation is constant for each type of infrastructure. For three types of infrastructure: transport, communication and power, equation (5) is modified as

$$ln(y^*) = \beta_\circ + \frac{\beta_1}{1-(\beta_{1+}\beta_2+\beta_3)} lns_t + \frac{\beta_2}{1-(\beta_{1+}\beta_2+\beta_3)} lns_c + \frac{\beta_2}{1-(\beta_{1+}\beta_2+\beta_3)} lns_{en} - \frac{(\beta_{1+}\beta_2+\beta_3)}{1-(\beta_{1+}\beta_2+\beta_3)}\ln(n+\delta) + u_t \ldots\ldots\ldots (6)$$

An increase in transport infrastructure, communication infrastructure and power infrastructure can have positive, negative or no impact on per capita income (GDP). It is simplified as

$$\frac{\partial ln(y^*)}{\partial lns_t} > 0, \qquad \frac{\partial ln(y^*)}{\partial lns_c} \gtreqless 0, \qquad \frac{\partial ln(y^*)}{\partial lns_{en}} > 0,$$

4. Econometric Model

The theoretical model explained in previous section shows that per capita output is the function of transport infrastructure, communication infrastructure and power infrastructure. Using theoretical model, we investigate the impact of economic infrastructure on long run economic growth by specifying following econometric model.

$$lnGDP_{pt} = \beta_\circ + \beta_1 lnkp_t + \beta_{2i} lnEI_t + u_t \ldots\ldots\ldots (7)$$

Where t indicates time period that is t = 1, 2,…, T, $lnGDP_g$ is the natural logarithm of per capita gross domestic product, kp is the private sector investment, EI is the measure of economic infrastructure such as transportation, communication and electricity etc. and u_t is the error term which is normally distributed and orthogonal to all explanatory variables. $\beta_\circ, \beta_1$, and $\beta_{2i}$are parameters to be estimated. Ordinary least square method can be used to estimate the relationship between infrastructure and per capita GDP. A number of empirical studies identify the problem of endogeneity in infrastructure variable in growth regression. Moreover reverse causality also exists between infrastructure and economic growth (see the studies of Loayza and Odawara, 2010; Sahoo and Dash, 2009). Reverse causality exists in the sense that infrastructure development depends on economic growth or economic growth demands infrastructure development.

If OLS method is used in the presence of endogeneity and reverse causation problems, the estimators would be biased and inconsistent. In order to fix these problems, we use cointegration technique known as autoregressive distributed lagged (ARDL) technique, developed by Pesaran et al. (2001). This is a new approach to estimate the long run relationship between variables irrespective of their order of integration, I(1) or I(0) or mutually cointegrated. They provide two sets of the asymptotic critical values for two polar conditions; one assumes that underlying variables are I (0), and other assumes that variables under consideration are I(1). They propose bound testing procedure to examine the long run relationship since critical values provide the critical values bounds for all set of underlying variables into I(1) and I(0). If F-statistics obtained through the Wald test lies outside the critical value bounds, then conclusive inference can be drawn without bother to know underlying variables are I(1), I(0) or mutually cointegrated. However situation would be reverse if the F-statistic falls inside the critical value bounds, an inconclusive inference can be drawn but it is necessary to check whether underlying variables are I(1) or I(0) before conclusive inference is made. Moreover ARDL approach is applicable to small sample size and it also works efficient even when model has any explanatory variable which is endogenous.

Step1:

Bounds Testing Method; we estimate the conditional unrestricted error correction model to find the long run relationship between dependent variables and explanatory variables. Therefore we estimate the following regression

$$\Delta lnGDP_{pt} = \alpha_{\circ} + \sum_{i=0}^{k-1} \beta_{1i} \Delta lnGDP_{p,t-i} + \sum_{i=0}^{k-1} \beta_{2i} \Delta lnK_{pt-i} + \sum_{i=0}^{k-1} \beta_{3i} \Delta \ln X_{t-i} + \beta_4 GDP_{g,t-1} + \beta_5 lnK_{pt-i} + \beta_6 \ln X_{t-1} + \varepsilon_t \dots\dots\dots (8)$$

In equation (8), k is the maximum number of lags in level of all underlying variables, Δ is the first difference operator and $\alpha_{\circ}$ is the drift parameter. Variable on left hand side is the per capita GDP and a variable on right hand side are explanatory variables at difference in k-1 lags and at level with one lag, β_s are the parameters to be estimated and u is the error term respectively.

We estimate equation (8) by using OLS method to examine the long run relationship among variable by employing the Wald test to check the null hypothesis of no co-integration $H_{\circ}: \beta_4 = \beta_5 = \beta_6 = 0$ against alternative hypothesis $H_1: \beta_4 \neq \beta_5 \neq \beta_6 \neq 0$ of co-integration among dependent and explanatory variables.

If F-statistics is greater than upper bound, then conclusive inference is drawn that there exists long relation among dependent and explanatory variables. On other side, if F-statistics less than lower bound, then null hypothesis is accepted with evidence of no long run relationship. If F-statistics falls inside the critical value bound, then inconclusive inference is drawn. It is required to investigate whether the underlying variables are integrated of order 1 or 0. However the critical values depend on whether model is with or without trend and drift (Pesaran et al., 2001).

Step 2: Once step 1 showed that there exists a long run relationship between dependent and explanatory variable using bound testing, then we estimate the long term and short term model. First we select the lag length by using appropriate lag length criteria such as Akaike Information Criteria (AIC), Schwartz Information Criteria (SIC) and HQC. For lung run relationship, we estimate the following equation

$$lnGDP_{pt} = \alpha_1 + \sum_{i=0}^{k-1} \beta_{1i} lnGDP_{p,t-i} + \sum_{i=0}^{k-1} \beta_{2i} lnK_{pt-i} + \sum_{i=0}^{k-1} \beta_{3i} \ln X_{t-i} + +v_t \dots\dots\dots (9)$$

Where α_1 is a drift parameter and β_s are parameters to be estimated to find out long run relationship among economic infrastructure, private investment and GDP per capita using general to specific method of Hendry (1995).

Step 3: Next we estimate the error correct model including the error correction term of estimated long run model with lagged one period. Again we use general to specific method of Hendry (1995). Short run relation is specified in following equation

$$\Delta lnGDP_{pt} = \alpha_{\circ} + \sum_{i=0}^{k-1} \beta_{1i} \Delta lnGDP_{p,t-i} + \sum_{i=0}^{k-1} \beta_{2i} lnK_{pt-i} + \sum_{i=0}^{k-1} \beta_{3i} \Delta \ln X_{t-i} + +\varphi ECT_{t-1} + e_t \dots\dots (10)$$

ECT is the error correction term and it is obtained through equation (10) as

$$\varphi ECT_{t-1} = lnGDP_{pt} - \alpha_1 - \sum_{i=0}^{k-1} \beta_{1i} lnGDP_{p,t-i} - \sum_{i=0}^{k-1} \beta_{2i} lnK_{pt-i} - \sum_{i=0}^{k-1} \beta_{3i} \ln X_{t-i}$$

Where, Δ is the first difference operator, β_s are short run parameters to be estimated and φ is the parameter that depicts speed of adjustment towards long run equilibrium. This model will undergo certain diagnostic tests.

Causality Analysis:

Since the ARDL approach confirms the long run cointegrating relationship among economic infrastructure, private and economic growth. But tt does not tell us about the direction of causality. Therefore, Vector Error Correction Method (VECM) approach is used to detect the direction of causality whether it is one way or two ways. Toda and Phillips (1993) assert that if long run cointegrating relationship exists among variables, then VECM approach can be used to ascertain the direction of causality. The VECM for lnGDP per capita, economic infrastructure (lnX_t), social infrastructure $(\ln Z_t)$ and private investment (K_{pt}) can be written as

$$\Delta lnGDP_{pt} = \alpha_1 + \sum_{i=0}^{k-1} \gamma_{1i} \Delta lnGDP_{p,t-i} + \sum_{i=0}^{k-1} \delta_{1i} \Delta \ln X_{t-i} + \sum_{i=0}^{k-1} \Delta lnK_{pt-i} + \varphi_1 ECT_{t-1} + e_{1t} \dots\dots (11)$$

$$\Delta \ln X_t = \alpha_2 + \sum_{i=0}^{k-1} \gamma_{2i} \Delta lnGDP_{p,t-i} + \sum_{i=0}^{k-1} \delta_{2i} \Delta \ln X_{t-i} + \phi_2 \sum_{i=0}^{k-1} \Delta lnK_{pt-i} + \varphi_2 ECT_{t-1} + e_{2t} \dots\dots (12)$$

$$\Delta \ln Z_t = \alpha_3 + \sum_{i=0}^{k-1} \gamma_{3i} \Delta lnGDP_{p,t-i} + \sum_{i=0}^{k-1} \delta_{3i} \Delta \ln X_{t-i} + \phi_3 \sum_{i=0}^{k-1} \Delta lnK_{pt-i} + \varphi_3 ECT_{t-1} + e_{3t} \dots\dots (13)$$

$$\Delta K_p = \alpha_4 + \sum_{i=0}^{k-1} \gamma_{4i} \Delta lnGDP_{p,t-i} + \sum_{i=0}^{k-1} \delta_{4i} \Delta \ln X_{t-i} + \phi_4 \sum_{i=0}^{k-1} \Delta lnK_{pt-i} + \varphi_4 ECT_{t-1} + e_{4t} \dots\dots (14)$$

Where ECT_{t-1} is the error correction term derived from long run cointegrating equation and its coefficient φ indicates the speed of adjustment from disequilibrium to equilibrium within one period. We can also separate direction of short run and long run Granger causality. The direction of short run Granger causality can be check by testing the joint significance of the parameters of differenced explanatory variables. The direction of long run Granger causality can be checked by testing the significance of the parameter of ECT using t-test.

This study is based on annual time series data, spanning from 1971-2014. Data of infrastructure variables are obtained from State Bank of Pakistan handbook, various issues of economic survey of Pakistan and WDI. Data of GDP per capita and private investment are collected from World Development Indicators (WDI). Economic infrastructure variables are measured as 1) Per capita electricity power consumption in KW; 2) Per capita energy use equivalent to kg of oil; 3) Railway freight million ton per km; 4) Air transport freight million ton per km; 5) High roads in Kilometer (km); 6) Fixed telephone subscription per 100 population.

This study also constructs composite economic infrastructure index (EII) by taking six indicators such as total telephone lines per 100 of population, Railway freight million ton per km, high roads in km, air transport freight million ton per km, per capita electricity power consumption in MW and per capita energy consumption (equivalent to oil per kg) using principal component analysis. We also construct sub-indices for transportation and power infrastructure.

Unit root Test: Before the use of ARDL, it is necessary to check the order of the integration of each variable to ensure that none of the variable is integrated of order 2 i.e. I(2). We use Augmented Dickey Fuller test and Philips Perron test to examine the order of integration by setting the null hypothesis that series has unit root problem against the alternative hypothesis that series is stationary. Akaike Information Criteria and Schwartz Information criteria are used for lag selection.

The results of ADF are reported in table 2[1]. The t-statistics show that growth rate of per capita GDP is stationary at level while all other variables are stationary at first difference which implies that these variables are integrated of order 1.

[1] We also test unit root problem by using Phillips Perron test and results are reported in table 1.B in appendix B.

Table 2: Results of Unit Root Test

	Level			First Difference		
Variables	**Without Trend**	**With Trend**	**Result**	**Without Trend**	**With Trend**	**Result**
Air transport Freight	-3.567	-1.868	NS	-5.137	-3.944	S
High roads	-1.239	1.100	NS	-2.225	-6.257	S
Railway Freights	-0.289	-3.427	NS	-6.536	-6.663	S
Fixed Telephone Lines	-0.917	-2.195	NS	-1.534	-5.192	S
Electricity consumption	-1.957	-0.551	NS	-5.519	-6.165	S
Energy Consumption	-1.192	-1.058	NS	-5.732	-5.834	S
Economic Infrastructure Index (EII)	-0.419	-1.173	NS	-5.603	-7.274	S
Transport Index	-0.824	-1.535	NS	-5.464	-7.515	S
Energy Index	-0.206	-2.441	NS	-5.169	-5.107	S
GDP per capita	-1.564	-1.607	NS	-5.678	-5.856	S
Private Investment	-1.529	-2.879	NS	-8.847	9.263	S
Growth rate	-5.264	-5.248	S			

Source: Author's own calculation. At 95% level of significance without trend, critical value is -2.931 and with trend it is -3.521 in level. Whereas at 95% level of significance and without trend, critical value is -2.933 in first difference and with trend it is -3.52. SIC is used for optimal lag selection. NS stands for non-stationary and S for stationary. * Shows those variables which are stationary without trend and insignificant with trend.

Long Run Relationship: The first step of ARDL technique is to estimate equation 9 in order to test the existence of long run cointegration relationship among the variables, and then use Wald test to compute F-test to check the joint significance of lagged variables.

Schwartz Bayesian Criterion is used for optimal lag length selection, and final ARDL model is chosen when estimated equations clear all diagnostic tests such as Lagrange Multiplier (LM) test for serial correlation, Ramsey reset test for functional form, Jarque Bera test for normality and heteroscedasticity test. Table 3 reports the F-statistics of the joint null hypothesis that the parameters of lagged variables are zero.

Overall results suggest that there exists a long run cointegrating relationship among GDP per capita, economic infrastructure variables, and private investment at typically 5% level of significance. The calculated F-statistic is greater than upper bound critical values and this implies that we reject the hypothesis of no long run co-integration relationship.

Table 3: ARDL Co-integration test

Estimated Models	Model1	Model 2	Model3
F-statistics	11.277**	44.456**	5.919**
Pesaran et al.(2001) critical values			
Lower bound	3.12	2.39	3.38
Upper bound	4.25	3.38	4.23
R-sqaure	0.927	0.820	0.690
Dw	2.47	2.23	2.010

Source: Authors own estimation. ** indicates the rejection of null hypothesis of no cointegrating relationship at 5% level of significance.

We present here three sets of model to analyze long run and short run estimates based on disaggregate and aggregate infrastructure variables in table 4 and 5. Column 1 of Tables 4 and 5 present the results of long run and short run impact of high roads, freights carried by railway, freights carried by air transport, telephone lines, energy use, electricity use and private investment on GDP per capita respectively. Columns 2 show the impact of transportation index, telephone lines, energy index and private investment on GDP per capita in Pakistan. Similarly columns 3 report the impact of composite economic infrastructure index (EII), and private investment on GDP per capita.

Column 1 of table 4 shows high roads impacts GDP per capita negatively. The reason is that there is an over public investment in high roads relative to other included sectors, therefore it has negative impact on GDP per capita. This result is consistent with previous study of Imran and Niazi (2011). Moreover, coefficients of ln(Freight Carried by railways), ln(Freight Carried by air transport) and fixed telephone lines do not have significant impact on GDP per capita. Coefficients of freights carried by railway and air transport though appear with positive sign but insignificant. However there are previous studies available that did not find the relationship between infrastructure and economic growth. For example Canning and Pedroni (2008) found that economic infrastructure does not have any impact on economic growth in panel of countries due to either undersupplied or oversupplied infrastructure. For instance, in case of Pakistan railway sector remain deprived and under supplied compared to other sectors.

Table 4: Long Run Estimates

Variables	Model 1	Model II	Model III
ln(High roads)	-0.377*		
	(0.000)		
Ln(Freight Carried by railways)	0.006		
	(0.536)		
ln(frieghts carried by air transport)	0.017		
	(0.510)		
Transportation Index		0.190	
		(0.000)	
ln(Telephone lines)	-0.022	-0.140	
	(0.464)	(0.000)	
ln(Electricity Use)	0.251**		
	(0.000)		
Ln(Energy use)	0.907**		
	(0.000)		
Energy Index		0.988**	
		(0.000)	
EII			0.465***
			(0.031)
Ln(Private Investment)	0.073	0.103	0.161**
	(0.000)	(0.000)	(0.000)
Trend		- 0.021*	0.010
		(0.001)	(0.455)
Constant	-3.759	5.220	5.114*
	(0.014)	(0.000)	(0.000)
χ^2_{SC}	3.929[0.050]	6.020[0.014]	2.110[0.146]
χ^2_{FF}	0.040[0.841]	0.341[0.559]	0.002[0.969]
χ^2_{N}	1.200[0.549]	0.251[0.882]	3.556[0.169]
χ^2_{H}	0.047[0.828]	0.412[0.521]	0.003[0.957]

*, ** and *** indicate 1%, 5% and 10% level of significance. χ^2_{SC} is the Lagrange Multiplier test of serial correlation;$\chi^2_{FF}$is the Ramsey reset test for functional form;
χ^2_{N} is the Jargue Bara test of Normality; and χ^2_{H} is the test of heteroscedasticity.

It is very interesting that the co-efficient of energy consumption and electricity consumption have positive and significant impact on long run lnGDP per capita. This result is also consistent with the previous literature (Chaudhary *et al.*, 2012). However, there is a possibility of reverse causality that an increase in GDP per capita increases the demand for energy and electricity respectively. Recent study of Alkhathlan and Javid (2013) supports this finding that the causality runs from GDP per capita to energy consumption and electricity consumption. Similarly, private investment has positive and significant impact on GDP per capita but reverse causation may exist between GDP per capita and private investment.

Column two of table 4 reveals that transportation index has positive and significant impact on growth. Moreover, the coefficients of energy index and private investment have positive effect on GDP per capita. Similarly, coefficient of fixed telephone lines has negative effect on economic growth due to over investment in fixed telephone lines. Nevertheless, these results do not correspond to the causal effect of economic infrastructure sub-indices on economic growth.

Column three of table 4 presents the impact of composite economic infrastructure index (EII) and private investment on economic growth. All these three variables have positive and significant impact on economic growth with the possibility of reverse causality.

Short Run Estimation

Similarly, we estimated the short run relationship among economic infrastructure; private investment and GDP per capita using error correction model and results are reported in table 5.

Table 5 indicates that coefficients of high roads, electricity consumption, energy consumption, and private investment positively and significantly impact GDP per capita in short run whereas freights carried by railways, freights carried by air transport have insignificant impact on economic growth respectively. Furthermore long run elasticities of electricity consumption, energy consumption and private investment are higher in magnitude than short run elasticities. This implies that there exists a monotonically increasing relationship between electricity consumption, energy consumption, private investment and GDP per capita. However, coefficient of high roads is lower magnitude in long run than short run. The coefficient of error correction term carried a negative sign with statistical significant at 1% and 5% level of significance. This has verified the existence of long run relationship between infrastructure and GDP per capita. We also examined the impact of sub-indices of infrastructure on GDP per capita in short run. Column 2 of table 5 reveals that transportation index, energy index and private investment have positive and significant impact on GDP per capita whereas coefficient of fixed telephone lines has negative and significant effect on per capita GDP. However, coefficient of error correction term has negative and significant impact on GDP per capita. Long run elasticities of transportation index, energy index (eindex) and private investment are greater in magnitude than short run elasticity.

Finally, we estimated the model using composite economic infrastructure index, and private investment as explanatory variables with GDP per capita as dependent variable. Column 3 revealed that these two explanatory variables positively and significant impact GDP per capita, whereas ECM has negative and significant impact on GDP per capita. Furthermore, long run elasticities of EII and private investment are higher in magnitude than short run elasticities.

Table 5: Short Run Elasticities

Variables	Model 1	Model II	Model III
Δln(High roads)	0.258*		
	(0.002)		
ΔLn(Freight Carried by railways)	0.005		
	(0.440)		
Δln(freights carried by air transport)	-0.014		
	(0.185)		
ΔTransportation Index		0.081**	
		(0.002)	
Δln(Telephone lines)	-0.014	-0.063**	
	(0.515)	(0.000)	
Δln(Electricity Use)	0.187**		
	(0.000)		
ΔLn(Energy Use)	0.580**		
	(0.000)		
ΔEnergy Index		0.730*	
		(0.000)	
ΔEII			0.105***
			(0.018)
Ln(Private Investment)	0.047*	0.042**	0.036**
	(0.000)	(0.000)	(0.002)
Constant	-2.122**	3.519**	1.158**
	(0.026)	(0.000)	(0.000)
(ECM)t-1	-0.700*	-0.366**	-0.226***
	(0.000)	(0.000)	(0.002)

*, ** and *** indicate 1%, 5% and 10% level of significance.

Next step is to estimate the VECM and Granger causality test. The existence of cointegrating relationship among variables, as given in table 3, shows the Granger Causality in these variables at least in one direction but it does not ascertain in which direction. In tables B2, B3 and B4 given in appendix B present the results of Granger causality test based on VECM for short term and long term.

The results of Granger Causality indicate that there exists unidirectional causality from GDP per capita (lnGDPP) to freights carried by rails (lnrw), freights carried by air transport (lnar), electricity consumption per capita (lnelc), energy consumption per capita (lnenr), and private investment (lnPI) in short run. However bidirectional causality is observed between electricity consumption and energy consumption.

Similarly, table A3 indicates the unidirectional causality from lnGDPP to transportation index (tindex) and energy index (eindex) but unidirectional causality is observed from lngfcp to lnGDPP respectively. Table A3 presents the results of Granger Causality for GDP per capita, transport index (Tindex), telephone lines (lntf), energy index (eindex) and private investment (lnPI). Results more or less remain same. Similarly, table A4 reports the results of Granger Causality based on VECM for GDP per capita, economic infrastructure index (EII) and private investment (lnPI). GDP per capita demands more Economic infrastructure and private investment.

6. Conclusions

Infrastructure development is vital for economic growth and development. Investment of economic infrastructure such as transportation, telecommunication and power facilitates the production process by reducing trade and transaction cost, accessing the markets and lowering the cost of doing business. It can also enhance the marginal productivity of capital and other additional inputs and accordingly strengthening the long run economic growth.

In this study, we contribute in literature by disaggregating economic infrastructure into transportation, telecommunication and power to capture its impacts on long run economic growth of Pakistan over the period 1971-2014 using ARDL approach. We examined the long run and short run relationship among economic infrastructure, private investment and GDP per capita. Our results indicate that there exist a long run relationship among economic infrastructure, private investment and economic growth. Particularly, high roads have negatively significant impact on GDP per capita in long run due to over investment in high roads infrastructure in Pakistan. Whereas railways and air transport freights have insignificant impact on GDP per capita. To some extent, it is convincing that long run growth is not determined by physical capital known as economic infrastructure such as roads, air transport etc (Solow, 1956) but in short run changes in economic infrastructure do impact economic growth (Solow, 1956).

However, per capita electricity consumption, per capita energy consumption and private investment have positive and significant impact on GDP per capita in short run and long run These findings are consistent with findings of previous studies (Sahoo and Dash, 2014; Qayyum and Khan, 2014; Sahoo and Dash, 2012). For parsimony analysis, transportation index, energy index and composite economic infrastructure index have been constructed using principal component analysis (PCA). Furthermore transport index and energy index have positive and significant impact on GDP per capita in long run and short run. Likewise private investment has positive impact on long run and short run growth in all estimated models. Overall economic infrastructure index has positive and significant impact on GDP per capita in short run and long run. To assess the direction of causality, Granger Causality test based on VECM has been used. Economic growth demands the economic infrastructure such as air transport freights, electricity consumption per capita, energy consumption per capita and private investment. Therefore we can say that unidirectional causality run from GDP per capita to economic infrastructure.

However, the major conclusion, we have drawn from this analysis is that economic infrastructure does support the long run economic growth of Pakistan. However there is a need to improve all sectors of economic infrastructure such as transport, communication and energy to boost the long run and short run economic growth. Especially, transport infrastructure is not adequate due to inadequate maintenance and over investment problems in high roads. Only the improvement in road interwork cannot bring any sustainable change in economic growth until locomotives and railroads infrastructure are not improved. Similarly there is a need to cope up with energy crisis, though its consumption increases over the time but shortage of electricity has affected economy adversely.

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Appendix A

Table A.1: Results of Unit Root Test (Phillips Perron Test)

	Level			First Difference		
Variables	**Without Trend**	**With Trend**	**Result**	**Without Trend**	**With Trend**	**Result**
Air transport Freight	-3.785	-2.997	NS	-5.285	-7.422	S
High roads	-1.843	0.525	NS	-5.709	-6.458	S
Railway Freights	-0.289	-2.043	NS	-6.536	-6.679	S
Fixed Telephone Lines	-0.705	-2.122	NS	-5.643	-5.450	S
Electricity consumption	-1.957	-0.551	NS	-5.546	-6.168	S
Energy Consumption	-1.169	-1.204	NS	-5.376	-5.862	S
Composite Index	-0.057	-2.191	NS	-5.618	-5.525	S
Transport Index	-0.758	-1.815	NS	-6.463	-6.564	S
Energy Index	-0.241	-2.306	NS	-5.169	-5.107	S
Private Investment	-1.529	-2.879	NS	-8.847	9.263	S
GDP per capita	-0.884	-1.515	NS	-5.736	-5.877	S
Growth rate	-5.264	-5.248	S			

Source: Author's own calculation. At 95% level of significance without trend, critical value is -2.933 and with trend it is -3.518 in level. Whereas at 95% level of significance and without trend, critical value is -2.933 in first difference and with trend it is -3.52. SIC is used for optimal lag selection. NS stands for non-stationary and S for stationary. * Shows those variables which are stationary without trend and insignificant with trend.

Table A.2; Granger Causality Test

	Short term t-statistics								Long Term t-stat
	LNGDPP	lnhr	lnrw	lnar	lntf	lnelc	lnenr	lnPI	ECT
LNGDPP		1.299	2.830***	3.777**	0.804	4.600**	5.323**	5.286**	-0.023***
		(0.254)	(0.093)	(0.019)	(0.370)	(0.031)	(0.021)	(0.022)	(0.060)
lnhr	0.015		0.985	0.508	0.743	0.226	0.109	0.982	0.027
	(0.903)		(0.321)	(0.476)	(0.389)	(0.635)	(0.741)	(0.322)	(0.187)
lnrw	0.011	0.248		0.444	0.000	0.003	0.085	0.203	-0.232**
	(0.918)	(0.619)		(0.505)	(0.995)	(0.959)	(0.771)	(0.652)	(0.028)
lnar	1.088	4.007**	2.452		1.900	0.616	0.412	0.247	-0.088
	(0.297)	(0.042)	(0.117)		(0.168)	(0.433)	(0.521)	(0.619)	(0.155)
lntf	0.034	1.626	1.104	4.398**		2.381***	2.177	0.923	0.070
	0.0.853	(0.202)	(0.294)	(0.036)		(0.087)	(0.140)	(0.337)	(0.151)
lnelc	0.139	0.002	0.132	0.268	0.020		3.754**	0.810	-0.023
	(0.709)	(0.963)	(0.716)	(0.605)	(0.888)		(0.020)	(0.368)	(0.299)
lnenr	0.057	0.154	0.005	0.449	0.050	0.566		0.020	-0.015
	(0.812)	(0.695)	(0.945)	(0.503)	(0.823)	(0.452)		(0.887)	(0.200)
lnPI	0.194	0.784	3.975**	0.085	0.066	0.013	0.032		-0.023
	(0.659)	(0.376)	(0.050)	(0.770)	(0.797)	(0.909)	(0.859)		(0.689)

Source: Author's own estimation

Table A3: Granger Causality Test

	Short term t-statistics					Long Term t-Stat
	LNGDPP	Tindex	Eindex	lntf	lnPI	ECT
LNGDPP		2.845***	10.047*	0.030	2.131	-0.343
		(0.092)	(0.007)	(0.564)	(0.345)	(0.113)
Tindex	1.385		0.561	4.420***	1.393	0.591**
	(0.709)		(0.807)	(0.107)	(0.498)	(0.024)
Eindex	0.998	4.666***		0.947	1.332	-0.113
	(0.802)	(0.097)		(0.429)	(0.514)	(0.443)
lntf	0.303	13.322*	6.903**		0.902	0.578
	(0.740)	(0.001)	(0.032)		(0.637)	(0.518)
lnPI	4.015**	5.608***	1.629	0.207		1.014
	(0.015)	(0.061)	(0.443)	(0.891)		(0.285)

Source: Author's own estimation

Table A4: Granger Causality Test

	Short term t-statistics			Long Term t-Stat
	lnGDPP	EII	lnPI	ECT
lnGDPP		7.792	6.501	-0.282
		(0.002)	(0.039)	(0.000)
EII	2.632		2.380	-0.033
	(0.268)		(0.304)	(0.364)
lnPI	7.626	5.895		0.574
	(0.022)	(0.053)		(0.230)

Source: Author's own estimation