The Determinants of Economic Growth: The Role of Infrastructure

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Abstract

The main objectives of the study were to examine the effect of infrastructure (i.e. railway network) on economic growth and to examine the direction of causality between economic growth and infrastructure using historical data covering the period of 1980 to 2016 and cointegration analysis. The findings from the study revealed a positive and significant effect of infrastructure on economic growth in the long-run however, the effect of infrastructure on economic growth was not significant in the short-run analysis. Also, the test of causality found a unidirectional causality running from economic growth to infrastructure. To increase economic growth in the United States, this study recommends that both the Federal and the State Government should increase its investments in infrastructure spending especially in railways.

Keywords: economic growth, infrastructure, inflation, trade deficit, United States

JEL Classification: EOO, H54, O4O, O18

Introduction

Infrastructure is the backbone of the U.S. economy and a necessary input to every economy's growth. It is critical to every nation's prosperity and households' social and economic welfare (American Society of Civil Engineers report, 2017). Empirical evidence tends to suggest that the availability and quality of infrastructure increases economic growth in both developed and developing countries (Canning & Pedroni, 2004; Holtz-Eakin & Schwartz, 1995). This implies that availability and investment in infrastructure, such as roads, railways, electricity, and human capital play an important role in increasing productivity and economic growth. On the other hand, poor infrastructure leads to low productivity, high unemployment, decreased personal income, and decrease international competitiveness of the country. Given the significant contribution that infrastructure played in economic growth, yet huge infrastructure gap still exists not only for developing countries but also advanced economies and particularly the United States (see Table 1). The World Economic Forum report (2016) indicates that globally, spending on basic infrastructure such as transport, power, water, and communications currently amounts to $2.7 trillion a year when it ought to be $3.7 trillion.

In the United States, the infrastructure gap is largely seen in almost all the sectors of the economy. Total infrastructure needs from between 2016 and 2025 is expected to be $4590 billion, meanwhile actual spending amount to $2526 billion with the funding gap of $2026 billion (ASCE, 2017). The country's public infrastructure spending is at 20-year low, as a result, America's roads, bridges and dams are rated D+ (American Society of Civil Engineers report, 2017). By 2020, U.S. infrastructure needs is expected to exceed $3.4 trillion which include $ 1.7 trillion for roads, bridges and transit; $ 736 billion for electricity and power grids; $391 billion for schools; $134 billion for airports; and $ 131billion for waterways and related projects (ASCE, 2017). A major factor that has contributed to huge infrastructure deficit in the U.S. has to do with inadequate investment by the federal government especially in road and transportation, water, and schools (see Table 1 and Figure 1 and 2).

Table 1: Cumulative Infrastructure Needs by System, 2016-2025 (Billion Dollars)

Infrastructure Systems	Total Needs	Estimated Funding	Funding Gap
Surface Transportation	2,042	942	1101
Water/Wastewater Infrastructure	150	45	105
Electricity	934	757	177
Airports	157	115	42
Inland Waterways and Marine Ports	37	22	15
Dams	45	5.6	39.4
Hazardous and Solid Waste	7	4	3
Levees	80	10	70
Public Parks and Recreation	114.4	12.1	102.3
Rail	154.1	124.7	29.4
Schools	870	490	380
Total	4590	2526	2064

Source: American Society of Civil Engineers, ASCE (2019)

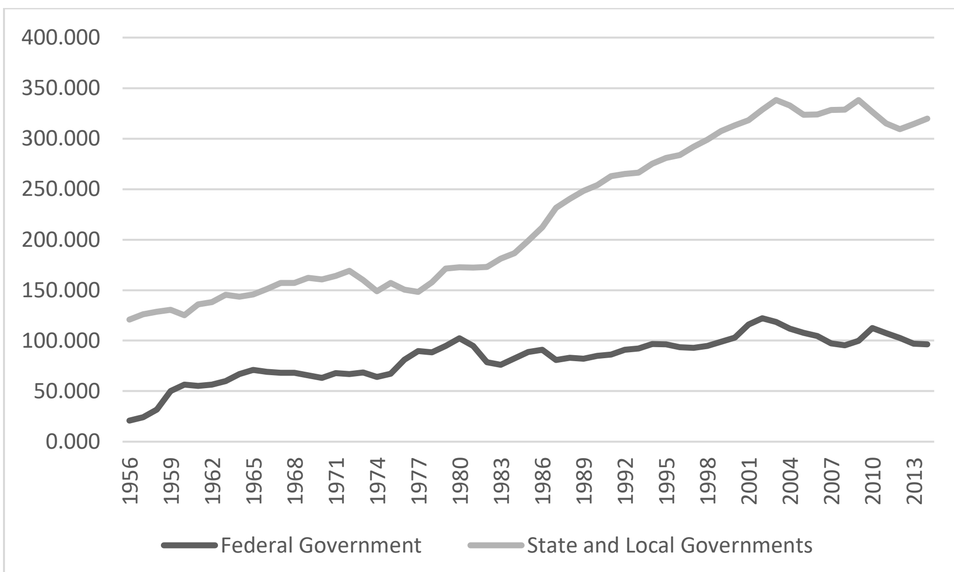

Figure 1: Public Spending on Transportation and Water Infrastructure, by level of Government (1956 to 2014)

Source: Congressional Office Budget and The Bureau of Economic Analysis (2019)

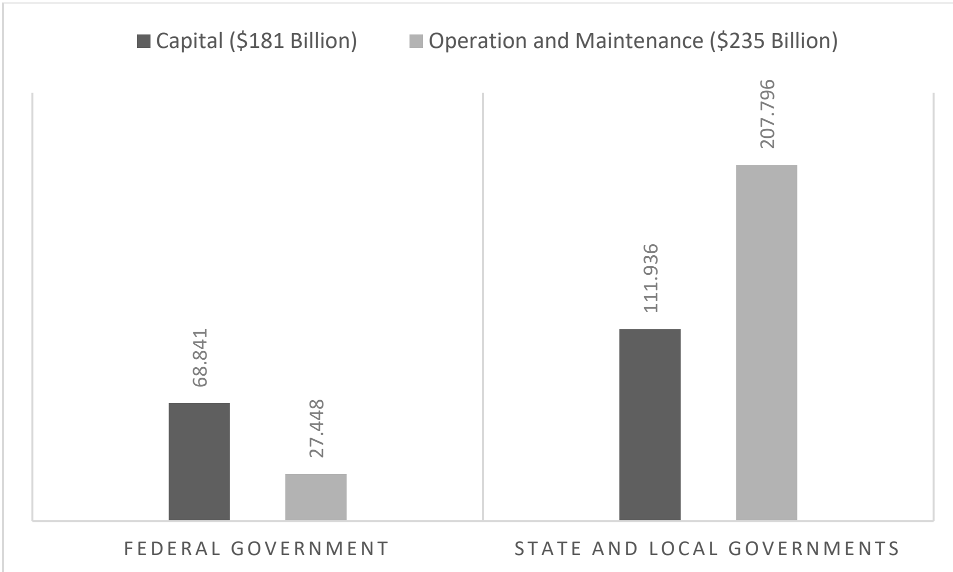

Figure 2: The Federal Government's and State and Local Government's Shares of Spending on Transportation and Water Infrastructure, by Category of Spending, 2014
Source: Congressional Office Budget and The Bureau of Economic Analysis (2019)

The deteriorating effect of the infrastructure gap does not only impact the quality and quantity of jobs and economic growth but also it has a negative implication on households' disposable income and welfare. The ASCE report (2017) stated that if this investment gap is not addressed the United States economy is expected to lose almost $4 trillion in GDP, resulting in a loss of about 2.5 million jobs and 7 trillion in lost business sales by 2025. Given the link between infrastructure and economic growth, there is the need to critically examine empirically the impact of infrastructure on economy growth in the United States.

Previous studies have extensively examined how variables such as human capital, government expenditure, foreign direct investments, terms of trade, fertility rate, inflation, and real exchange rates among others impact on economic growth (Barro, 1996; Asheghian, 2016 Rupasingha, Goetz & Freshwater 2002; Zestos and Tao, 2002). However, despite the significant contribution of infrastructure in stimulating economic growth a lot of empirical studies have not been conducted in this area as far as the United States economy is concerned. Therefore, the objectives of this study are two-folds. The first objective is to examine the long-run and short-run effects of infrastructure on economic growth in the United States. And the second objective is to examine the direction of causality between infrastructure and economic growth. It is expected that the outcome of the study will not only contribute to both empirical literature and methodology but will also contribute to policy formulation in government institutions. The rest of the paper is organized as follows. The first section presents a review of relevant literature, followed by the methodology. The next section presents the results and discussions and the last section presents the conclusion and recommendations.

Literature Review

A plethora of studies have examined the factors influencing economic growth. Most of these studies have employed either cross-section or panel analysis and only few studies exist on a single country case. In addition, the impact of variables such as human capital, education, fiscal policy, foreign direct investment inflows, inflation, and real exchange rates have been examined extensively in literature however, only few studies have focused on the role of infrastructure in influencing economic growth. This research essentially seeks to fill this gap in the literature. In this section, I present briefly some empirical literature on determinants of economic growth.

Using time series data covering the period of 40 years, Asheghian (2016) employed the Beach Mackinnon technique to examine the determinants of economic growth over time and also examined if there is any time-series support for the FDI-led growth hypothesis in the United States. The findings from the study revealed that the major determinants of economic growth in the United States are total factor productivity growth, domestic investment growth, and FDI growth. Again, there exists a unidirectional causality running from FDI growth to economic growth. Similarly, the findings also suggest a unidirectional causality running from FDI growth to total factor productivity. The study suggests that FDI has a significant impact on economic growth in the United States and hence policy makers should devise policies to stimulate increase in FDI inflows.

In a similar study, Canning and Pedroni (2004) investigated the long run consequences of infrastructure provision (i.e. telephones, electricity generating capacity, and paved roads) on per capita income in a panel of countries over the period 1950-1992. The study employed simple panel-based tests. This test enables the authors to isolate the sign and direction of the long-run effect of infrastructure on income in a manner that is robust to the presence of unknown heterogeneous short-run causal relationships. The findings of the study found evidence that infrastructure does induce long-run growth effects however, a great deal of variation was found in the results across individual countries.

In addition, employing annual time-series data (1948-1996) and the vector error correction (VEC) model, Zestos and Tao (2002) analyzed the causal relationship between the growth rates of exports, imports, and the GDP growth of Canada and the United States. The findings revealed a bidirectional causality between the foreign sector and GDP growth for Canada, however a weaker relationship was found between the foreign sector and GDP growth for United States. Their results also showed that Canada is more trade dependent than the United States.

In their empirical study, Rupasingha, Goetz and Freshwater (2002) examined the social and institutional factors as a determinant of economic growth in the United States. Thus, controlling for spatial dependence, they assess the contribution of differences in social and institutional variables on economic growth rates per capita for counties in the United States. The results from their study revealed that, ceteris peribus, social and institutional variables explain some of the differences in convergence rates among counties. Specifically, their results showed that ethnic diversity is associated with faster economic growth rates. Also, higher levels of income inequality are associated with lower growth rates and higher levels of social capital have a positive effect on economic growth rates.

From the review of literature, it was clear that most of the studies on the determinants of economic growth in the United States seem to focus much how variables such as human capital, education, fiscal policy, foreign direct investments, institutions, inflation, exchange rates etc. affect economic growth however, only few studies have focused on the role of infrastructure in influencing economic growth. The only study on economic growth and infrastructure was Canning and Pedroni (2004). However, their study was a cross-country analysis and did not specifically focused at the United States. This study sought to fill these gaps that exist in the literature as far as economic growth and infrastructure are concerned.

Methodology

Theoretical model

The main objective of the study was to examine the determinants of economic growth in the United States. To do that, I employed the Solow-Swan growth model. The model assumes that economic growth is a function of capital accumulation, labor or population growth, and technological change. This is shown below;

$$Y_t = K_t^{\alpha} L_t^{1-\alpha} A_t \quad (1)$$

Where Y is economic growth, K is capital, L is labor or population growth, and t is time. A is total factor productivity or technology. I extend this growth model by assuming that technological progress can be influenced by infrastructure development (INFRA). This enables me to specify A as follows:

$$A_t = \varphi INFRA_t^{\delta} Z_t^{\mu} \quad (2)$$

where INFRA is infrastructure development and Z is other factors that may influence the state of technology. Substituting Equation (2) into Equation (1), gives:

$$Y_t = \varphi INFRA_t^{\delta} K_t^{\alpha} L_t^{1-\alpha} Z_t^{\mu} \quad (3)$$

Diving both sides by labor and taking logs, equation (3) can be modeled as follows:

$$Y_t = \vartheta_0 + \vartheta_1 K_t + \vartheta_2 L_t + \vartheta_3 INFRA_t + \mu_t \quad (4)$$

where Y, K, L, INFRA represent the log of real GDP per capita, log of real capital stock per capita, log of labor force, and log of infrastructure development respectively.

Econometric Model and Data Description

The study adapts equation (4) and incorporate other determinates of economic growth in U.S. The empirical model for the study is specified by equation (5).

$$lnY_t = \psi_0 + \psi_1 lnINFRA_t + \psi_2 lnINF_t + \psi_3 lnIR_t + \psi_4 lnREER_t + \psi_5 lnTDF_t + \varepsilon_t \quad (5)$$

Where Y is gross domestic product (GDP) growth rates to measure economic growth, INFRA is infrastructure proxied by railway lines (total-route km), INF is inflation, consumer prices (annual %) (2010=100), IR is lending interest rates, REER is real effective interest rate (2010=100), TDF is trade deficit (i.e. export minus import), ϵ_t is the error term, ψ_0 is the intercept parameter, ψ_1, ψ_2, ψ_3 , and ψ_4 measures the elasticities. Based on the review of literature the a priori expected signs of the variables are as follows: $\psi_1 > 0, \psi_2 > 0 \; or \; < 0, \psi_3 > 0 \; or \; < 0, \psi_4 >$

$0\ or < 0, \psi_5 > 0\ or\ < 0.$ The study employs annual time series data covering the period of 1980 to 2016. All the data for the study were gleaned from World Bank (WDI).

Estimation technique

Economic theory often postulates that certain pairs of economic variables should be linked by a long-run economic relationship. Given that macroeconomic variables are interrelated, the study adopts a dynamic vector autoregressive regression (VAR) estimation which explores both cointegration and Granger causality analysis. The choice of this approach is to capture both the long run and short run dynamics among the variables and to address the possible endogeneity bias in the structural model. The VAR estimation procedures are as follows;

Unit Root Tests

Unit root test is expected to be the first step to be taken in time series regression analysis. The reason for conducting this test is to distinguish between stationary and non-stationary variables to come up with statistically reliable results. To test for stationarity in the variables, I employed the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test. The test procedures are shown below;

$$Y_t = \alpha + \beta t + \rho Y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-1} + \varepsilon_t \qquad (6)$$

Where, Y_t is the dependent variable in question, t is a time trend, Δ is the difference operator, and ε_t is a white noise process. Using OLS, I first run the unrestricted regression and the restricted regressions specified by equation (7) and (8):

$$Y_t - Y_{t-1} = \alpha + \beta t + (\rho - 1)Y_{t-1} + \sum_{j=1}^{p} \lambda_j \Delta y_{t-1} \qquad (7)$$

$$Y_t - Y_{t-1} = \alpha + \sum_{j=1}^{p} \lambda_j \Delta y_{t-1} \qquad (8)$$

To test whether restrictions $(\beta = 0, \rho = 1)$ hold, the F-Statistic was calculated. Dickey and Fuller used F-statistic instead of the t-statistic which they proved to be inappropriate. If the calculated F-statistic is less than the critical values generated by MacKinnon (1996), the null hypothesis is rejected and the alternate hypothesis that the variable is stationary is accepted. In addition to ADF test, the Phillips-Perron (PP) test was performed to check for the presence of structural breaks.

Cointegration test

The purpose of conducting cointegration analysis is to test for the presence of long-run relationship among the variables. To test for the cointegration among the variables, the study employed the Johansen (1991) and Johansen (1992) technique. The testing procedure is shown below;

$$Y_t = \alpha + \beta X_t + \varepsilon_t \qquad (9)$$

We run a simple OLS regression on Equation (9) and then test whether the residuals, ε_t from this regression are stationary. If Y_t and X_t are not co-integrated, any linear combination among them will be non-stationary and therefore, the residuals will be nonstationary (Pindyck and Rubinfeld, 1998).

Granger Causality

The VAR estimation is grounded on the assumption that variables are all endogenous. To be able to see if the variables are endogenous I performed the granger causality test developed by Granger and Newbold (1988). The a priori expectation is to reject a unidirectional causality among the endogenous variables.

VAR Estimation

Once cointegration has been established, the VAR estimation can be employed. The choice of VAR technique is deemed appropriate because the variables are interrelated and because of the possible endogeneity bias in the structural equation (equation (5)). The mathematical representation of a VAR is shown below:

$$Y_t = \alpha + \vartheta_1 Y_{t-1} + \cdots + \vartheta_p Y_{t-p} + \psi Z_t + \varepsilon_t \quad (10)$$

Where Y_t is vector of endogenous variables, Z_t is vector of exogenous variables, $\vartheta_1 \cdots \vartheta_p$ and ψ are the matrix of unknown coefficients to be estimated, ε_t is vector of error terms or innovations. In addition, the AIC and SIC lag length selection criteria was employed. The short-run dynamic coefficients are obtained by estimating an error correction model associated with the long run estimates. This is specified below:

$$Y_t = \alpha + \vartheta_1 Y_{t-1} + \cdots + \vartheta_p Y_{t-p} + \psi Z_t + \lambda ECM_{t-1} + \varepsilon_t \quad (11)$$

Where ECM_{t-1} is the error correction term and λ is the speed of adjustment.

Results and Discussions

This section of the paper presents the results of the study. The objectives of the study were first to examine both the long-run and short-run relationship between infrastructure and economic growth and secondly, to examine the direction of causality between economic growth and infrastructure in U.S. The summary statistics of the data showed that on average economic growth rates within the study period is 2.6% with the minimum and maximum growth rates being -2.7% and 7.2% respectively. Infrastructure spending within the period averaged $204,620.0 billion with minimum and maximum infrastructure spending averaging $157515.3 billion and $265,841.9 billion respectively. Real exchange rates average 1.11% with minimum and maximum exchange rates averaging 0.95% and 1.09% respectively, inflation rate within the study period averaged 0.76% with minimum and maximum exchange rates averaging 0.38% and 1.1%, average interest rates within the period is 7.5% with minimum and maximum interest rates averaging 3.25% and 18.87% respectively. Skewness and Kurtosis test showed that all the variables are normally distributed except real domestic product, real exchange rates and interest rates (see Table 2).

Table 2: Summary Statistics

	GDP	REER	INF	IR	INFRA	TDF
Mean	2.618	111.195	75.619	7.597	204620	-3.01E+11
Median	2.746	108.711	74.755	7.994	213258.1	-1.63E+11
Maximum	7.259	108.703	110.067	18.87	265841.9	-1.25E+10
Minimum	-2.776	95.131	37.789	3.25	157515.3	-7.71E+11
Std.Dev.	1.932	12.459	22.019	3.708	34615.45	2.50E+11
Skewness	-0.686	1.237	0.002	0.935	-0.013	-0.42
Kurtosis	4.139	4.093	1.783	3.962	1.624	1.679
Jarque-Bera	4.905	11.274	2.284	6.82	2.842	3.778
Probability	0.086	0.00356	0.319	0.033	0.241	0.151
Sum	96.869	4114.23	2797.895	281.092	7570940	-1.11E+13
Sum Sq. Dev	134.429	5587.87	17454.47	495.093	4.31E+10	2.26E+24

Prior to the cointegration analysis, I performed out a unit root test (i.e. ADF and PP) on all the variables to investigate their stationarity properties (see Table 3 and Table 4). The results showed that except for real effective exchange rate (REER) that is stationary at level, all the other variables were stationary at their first differenced. However, for the purpose of cointegration analysis and also to do away with the issue spurious regression, I ensured that all the variables are integrated of the same order (i.e. I(1)). Similarly, by plotting all the variables in levels, it was observed that none of the variables were stationary, however, when all the variables were plotted again using their first difference they became stationary (see Appendix 1 am 2).

Table 3: Unit Root Test-Augmented Dickey Fuller (Levels)

Var	ADF		Lag	Var	ADF		Lag	OI
	Statistic	P-Value			Statistic	P-Value		
GDP	0.492	0.984	1	DGDP	-3.927	0.005	0	I(1)
INF	-1.286	0.626	0	DINF	-5.229	0.001	0	I(1)
IFRA	-0.665	0.843	0	DIFRA	-4.761	0.001	0	I(1)
REER	-3.139	0.033	3	DREER	-3.870	0.005	0	I(1)
IR	-1.252	0.640	2	DIR	-5.369	0.000	1	I(1)
TDF	-1.047	0.726	0	DTDF	-5.532	0.000	0	I(1)

Note: D indicates first differenced. OI indicates order of integration.

Table 4: Unit Root Test-Phillip-Perron ((Levels)

Var	PP		BW	Var	PP		BW	OI
	Statistic	P-Value			Statistic	P-Value		
GDP	1.018	0.996	6	DGDP	-3.598	0.011	10	I(1)
INF	-1.212	0.658	1	DINF	-5.226	0.001	2	I(1)
IFRA	-0.716	0.830	1	DIFRA	-4.721	0.001	2	I(1)
REER	-2.173	0.218	2	DREER	-3.730	0.008	4	I(1)
IR	-1.225	0.653	2	DIR	-4.704	0.000	27	I(1)
TDF	-1.047	0.726	0	DTDF	-5.532	0.000	1	I(1)

Note: D indicates first differenced. OI indicates order of integration.

The correlation analysis was conducted, and the results are presented in Table 5. This test was done to check for the degree and extent of association that exist between the regressors and economic growth in the United States. The test found a negative correlation between exchange rate, interest rates, trade deficit and economic growth (GDP), inflation and infrastructure were found to be positively correlated to economic growth.

Table 5: Correlation Analysis

	LNGDP	LNREER	LNINF	LNIR	LNINFRA	LNTDF
LNGDP	1	-0.417	0.986	-0.823	0.975	-0.485
LNREER	-0.418	1	-0.457	0.399	-0.456	-0.267
LNINF	0.986	-0.457	1	-0.874	0.955	-0.389
LNIR	-0.829	0.399	-0.874	1	-0.758	0.333
LNINFRA	0.975	-0.456	0.956	-0.757	1	-0.467
LNTDF	-0.485	-0.267	-0.389	0.333	-0.467	1

Interestingly, the results of both trace statistic and maximum eigenvalue Johansen cointegration tests show the presence of 3 cointegration among the variables (see Table 7 and 8). This suggests that the null hypothesis of no cointegration is rejected at 5 percent level of significance. The presence of cointegration confirms that there is a dynamic long-run causal relationship the among the variables. However, to get ideal lag length for the VAR estimation, the lag order selection criterion was performed. The appropriate lag length of 2 was selected for the estimation based on the Akaike information Criterion (AIC) and Hannan-Quinn Information (HQ) (see Table 8).

Table 7: Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistics	0.05 Critical Value	Prob**
None*	0.779	148.61	95.754	0.000***
At most 1*	0.716	95.726	69.819	0.000***
At most 2*	0.566	51.697	47.856	0.021**
At most 3	0.275	22.458	29.797	0.274
At most 4	0.221	11.21	15.494	0.199
At most 5	0.068	2.465	3.841	0.116

Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 8: Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob**
None*	0.779	52.884	40.078	0.001***
At most 1*	0.716	44.029	33.877	0.002***
At most 2*	0.566	29.239	27.584	0.030**
At most 3	0.275	11.248	21.132	0.623
At most 4	0.221	8.744	14.265	0.308
At most 5	0.068	2.466	3.841	0.116

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
*denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Table 9: Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	92.799	NA	2.83E-10	-4.959	-4.693	-4.868
1	338.689	393.424	1.81E-15	-16.954	-15.087*	-16.309
2	401.092	78.449*	4.83e-16*	-18.462*	-14.996	-17.266*

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

The long-run and short-run results of the study are presented in Table 10 and Table 11 respectively. The results revealed a positive and significant relationship between economic growth and lagged GDP growth. That is, one percent increase in lagged GDP increases current economic GDP by about 60.11%. In addition, the study provides evidence of a positive and significant relationship between growth and infrastructure in the long run, however, the effect of infrastructure on economic growth was insignificant in the short run. One percent increase in infrastructure increases economic growth by 20.80% in the long-run. The result suggest that infrastructure development or investment is favorable to economic growth in U.S. Also, in the first quarter, inflation was found to be negatively related to economic growth in both short-run and long-run. However, in the second quarter, high inflation leads to high economic growth. The result also revealed a positive relationship between exchange rates and economic growth in both short-run and long-run in the first quarter but in the long-run exchange rates exerted a negative effects US economic growth. Also, the study recorded a negative and insignificant relationship between trade deficit and economic growth in the first quarter. This result suggest that trade deficit impede economic growth in the United States.

Table 10: VAR results (Long-Run Estimates)

var	GDP	INFRA	INF	IR	REER	TDF
GDP(-1)	0.601***	-1.362	0.112	1.304	0.408	0.583
	(0.236)	(0.744)	(0.159)	(2.018)	(0.874)	(0.592)
	[2.546]	[-1.831]	[0.704]	[0.646]	[0.467]	[0.985]
GDP(-2)	0.276	1.977***	0.059	1.093	-0.518	-0.918
	(0.248)	(0.784)	(0.168)	(2.125)	(0.920)	(0.623)
	[1.113]	[2.522]	[0.351]	[0.514]	[-0.563]	[-1.474]
INFRA(-1)	0.208***	0.867***	-0.021	0.974	0.561	-0.441
	(0.098)	(0.307)	(0.066)	(0.833)	(0.360)	(0.244)
	[2.122]	[2.824]	[-0.318]	[1.169]	[1.558]	[-1.807]
INFRA(-2)	-0.128	-0.172	0.038	0.004	-0.227	-0.002
	(0.075)	(0.237)	(0.051)	(0.642)	(0.278)	(0.188)
	[-1.707]	[-0.726]	[0.745]	[0.006]	[-0.817]	[-0.011]
INF(-1)	-1.136***	-3.499***	0.840***	-13.856***	1.014	1.736***
	(0.315)	(0.992)	(0.212)	(2.691)	(1.165)	(0.789)
	[-3.606]	[-3.527]	[3.962]	[-5.149]	[0.870]	[2.200]
INF(-2)	1.100***	3.130***	-0.017	9.757***	-1.185	-1.123
	(0.254)	(0.799)	(0.171)	(2.166)	(0.938)	(0.635)
	[4.331]	[3.917]	[-0.099]	[4.505]	[-1.263]	[-1.769]
IR(-1)	0.010	0.103	0.013	0.787***	-0.088	0.042
	(0.021)	(0.068)	(0.014)	(0.184)	(0.080)	(0.054)
	[0.476]	[1.514]	[0.929]	[4.277]	[-1.100]	[0.778]
IR(-2)	-0.023	-0.121***	-0.025***	-0.457***	0.058	0.038
	(0.019)	(0.058)	(0.012)	(0.158)	(0.069)	(0.046)
	[-1.211]	[-2.086]	[-2.083]	[-2.892]	[0.841]	[0.826]
REER(-1)	0.079	-0.156	-0.052	-0.398	1.180***	-0.333***
	(0.057)	(0.178)	(0.038)	(0.484)	(0.209)	(0.142)
	[1.386]	[-0.876]	[-1.368]	[-0.822]	[5.646]	[-2.345]
REER(-2)	-0.050	-0.176	0.010	-1.622***	-0.217	-0.212
	(0.090)	(0.284)	(0.061)	(0.773)	(0.335)	(0.227)
	[-0.556]	[-0.619]	[0.164]	[-2.098]	[-0.648]	[-0.934]
TDF(-1)	-0.023	-0.727	-0.012	-1.805	0.205	0.691***
	(0.120)	(0.378)	(0.081)	(1.027)	(0.445)	(0.301)
	[-0.192]	[-1.923]	[-0.148]	[-1.758]	[0.461]	[2.294]
TDF(-2)	0.029	0.554***	0.020	1.385***	0.125	-0.336
	(0.076)	(0.238)	(0.051)	(0.646)	(0.280)	(0.189)
	[0.382]	[2.328]	[0.392]	[2.144]	[0.447]	[-1.778]
C	0.830	1.169	-1.057	-11.061	-2.694	9.537***
	(1.361)	(4.287)	(0.916)	(11.628)	(5.036)	(3.409)
	[0.609]	[0.273]	[-1.154]	[-0.951]	[-0.535]	[2.798]
R-Squared	0.997	0.986	0.999	0.964	0.879	0.948
Adj. R-Squared	0.995	0.979	0.999	0.944	0.813	0.92

Sum sq. resids	0.004	0.035	0.002	0.259	0.049	0.022
S.E. equation	0.013	0.04	0.009	0.108	0.047	0.032
F-Statistic	559.62***	131.46***	3077.14***	48.457***	13.306***	33.42**
Log likelihood	111.28	71.139	125.14	36.215	65.5	79.155
Akaike AC	-5.616	-3.322	-6.408	-1.327	-2.91	-3.78
Schwarz SC	-5.039	-2.745	-5.830	-0.749	-2.422	-3.203
Mean dependent	10.634	14.495	4.315	1.859	4.706	-0.232
S.D. dependent	0.179	0.274	0.282	0.457	0.109	0.112
Determinant resid covariance (dof adj)			5.36E-20			
Determinant resid covariance			3.31E-21			
Log likelihood			527.296			
Akaike information Criterion			-25.674			
Schwarz criterion			-22.208			

Note: ****, **, * indicate 1%, 5%, and 10% significance level*

The error correction term (ECT (-1)) is negative as expected and statistically significant. The error correction term explains the validity of an equilibrium relationship among the variables used for the cointegration test. The speed of adjustment indicates that approximately about 11.78 percent of the short-run disequilibrium is corrected in the long-run. The test of causality also revealed a unidirectional causality running from economic growth to infrastructure (see Table 6). This test suggests that investments in economic growth could in turn contribute to further infrastructure investments. More so, the test revealed a bidirectional causality between inflation, interest rates, and economic growth.

Table 11: VECM Results (Short-Run Estimates)

Var	DGDP	DINFRA	DINF	DIR	DREER	DTDF
ECM(-1)	-0.118***	-0.326***	-0.033	0.239	0.361***	-0.06
	(0.044)	(0.126)	(0.027)	(0.476)	(0.132)	(0.108)
	[-2.682]	[-2.579]	[-1.222]	[0.502]	[2.735]	[-0.556]
DGDP(-1)	0.067	-0.809	0.219	2.157	-0.071	-0.162
	(0.252)	(0.727)	(0.152)	(2.739)	(0.759)	(0.619)
	[0.266]	[-1.113]	[1.441]	[0.788]	[-0.093]	[-0.262]
DINFRA(-1)	0.094	0.113	-0.053	0.216	0.374	0.187
	(0.085)	(0.246)	(0.052)	(0.927)	(0.257)	(0.209)
	[1.106]	[0.459]	[1.019]	[0.233]	[1.455]	[0.895]
DINF(-1)	-0.576***	-1.952***	0.381***	-4.101***	1.346***	0.121
	(0.189)	(0.544)	(0.114)	(2.051)	(0.568)	(0.463)
	[-3.048]	[-3.588]	[3.342]	[-1.999]	[2.370]	[0.261]
DIR(-1)	-0.009	0.069	0.015	0.288	-0.036	0.043
	(0.020)	(0.057)	(0.012)	(0.215)	(0.059)	(0.048)
	[-0.450]	[1.211]	[1.250]	[1.340]	[-0.610]	[0.897]
DREER(-1)	0.133	0.025	-0.038	-0.548	0.263	-0.286

	(0.067)	(0.192)	(0.040)	(0.725)	(0.201)	(0.164)
	[1.985]***	[0.130]	[-0.950]	[-0.756]	[1.310]	[-1.753]
DTDF(-1)	-0.052	-0.295	0.020	-0.154	0.039	0.486***
	(0.072)	(0.209)	(0.044)	(0.786)	(0.218)	(0.177)
	[-0.722]	[-1.411]	[0.455]	[0.196]	[0.179]	[2.746]
C	0.030***	0.091***	0.014***	0.049	-0.047	-0.004
	(0.008)	(0.024)	(0.005)	(0.090)	(0.025)	(0.020)
	[3.750]	[3.792)	[2.800]	[0.544]	[-1.88]	[-0.200]
R-squared	0.435	0.423	0.575	0.387	0.474	0.553
Adj. R-Squared	0.289	0.274	0.465	0.228	0.338	0.438
Sum sq. resid	0.007	0.055	0.002	0.792	0.061	0.040
S.E. equation	0.016	0.045	0.010	0.171	0.047	0.039
F-statistic	2.972***	2.834***	5.228***	2.432***	3.476***	4.789***
Log likelihood	100.08	63.057	117.72	16.632	61.541	68.701
Akaike AIC	-5.262	-3.146	-6.270	-0.493	-3.059	-3.469
Schwarz SC	-4.907	-2.791	-5.914	-0.138	-2.703	-3.113
Mean dependent	0.017	0.018	0.028	-0.048	0.001	-0.005
S.D. dependent	0.019	0.053	0.013	0.195	0.058	0.052
Determinant resid covariance (dof adj.)				2.42E-19		
Determinant resid covariance				5.09E-20		
Log likelihood				479.434		
Akaike Information criterion				-24.31		
Schwarz Information criterion				-21.91		

Note: ****, **, * indicate 1%, 5%, and 10% significance level, D is first differenced.*

The impulse-response analysis presented in Appendix 1 tells us how the variables change assuming there is one Standard deviation (S.D) shock to innovations. From the impulse response analysis, it can be observed that when there is one S.D shock to innovations, both economic growth and infrastructure decrease continuously even though they remain positive. For instance, external shock such as US-China trade war is a downside risk to US economic growth. Again, one S.D shock to innovations causes inflation to decrease, attains a minimum, increase again and then declines eventually. Furthermore, one S.D shock to innovations causes both real exchange rates and trade deficits to decline and attains a negative value. On the contrary, one S.D shock to innovations cause interest rates to initially declines, attains a negative value and then back to the equilibrium.

Conclusion and Recommendation

The study used historical data covering the period of 1980 to 2016 and cointegration analysis to examine the effect of infrastructure (i.e. railway network) on economic growth and to examine the direction of causality between economic growth and infrastructure in the United States. The results from the study found a positive and significant effect of infrastructure on economic growth in the long-run however, the effect of infrastructure on economic growth was not significant in the short-run analysis. The test of causality found a unidirectional causality running from economic growth to infrastructure. To increase economic growth in the United States, this study recommends that both the Federal Government and the State Government could increase investments in infrastructure especially in railways. The current study contributes to both empirical literature and methodology. In terms of literature, previous studies focused so much on human capital, fiscal policy, foreign direct investments, inflation, exchange rates etc. and how they affect economic growth. This study focused extensively on how infrastructure (i.e. railways network) affect economic growth. Also, regarding the methodology, the study employed a dynamic VAR analysis and error correction model to investigate both the long-run and short-run effects of infrastructure on economic growth in U.S.

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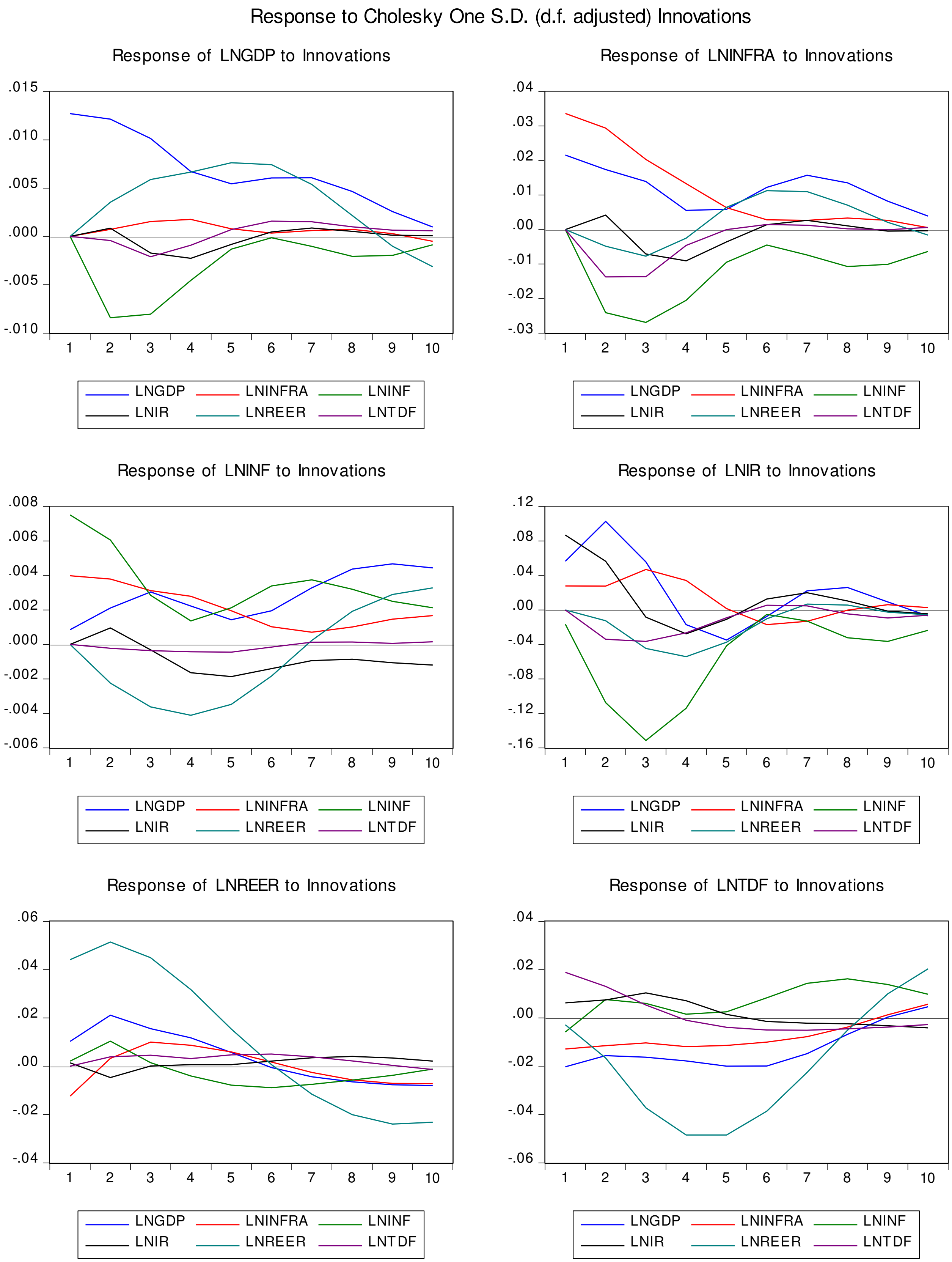
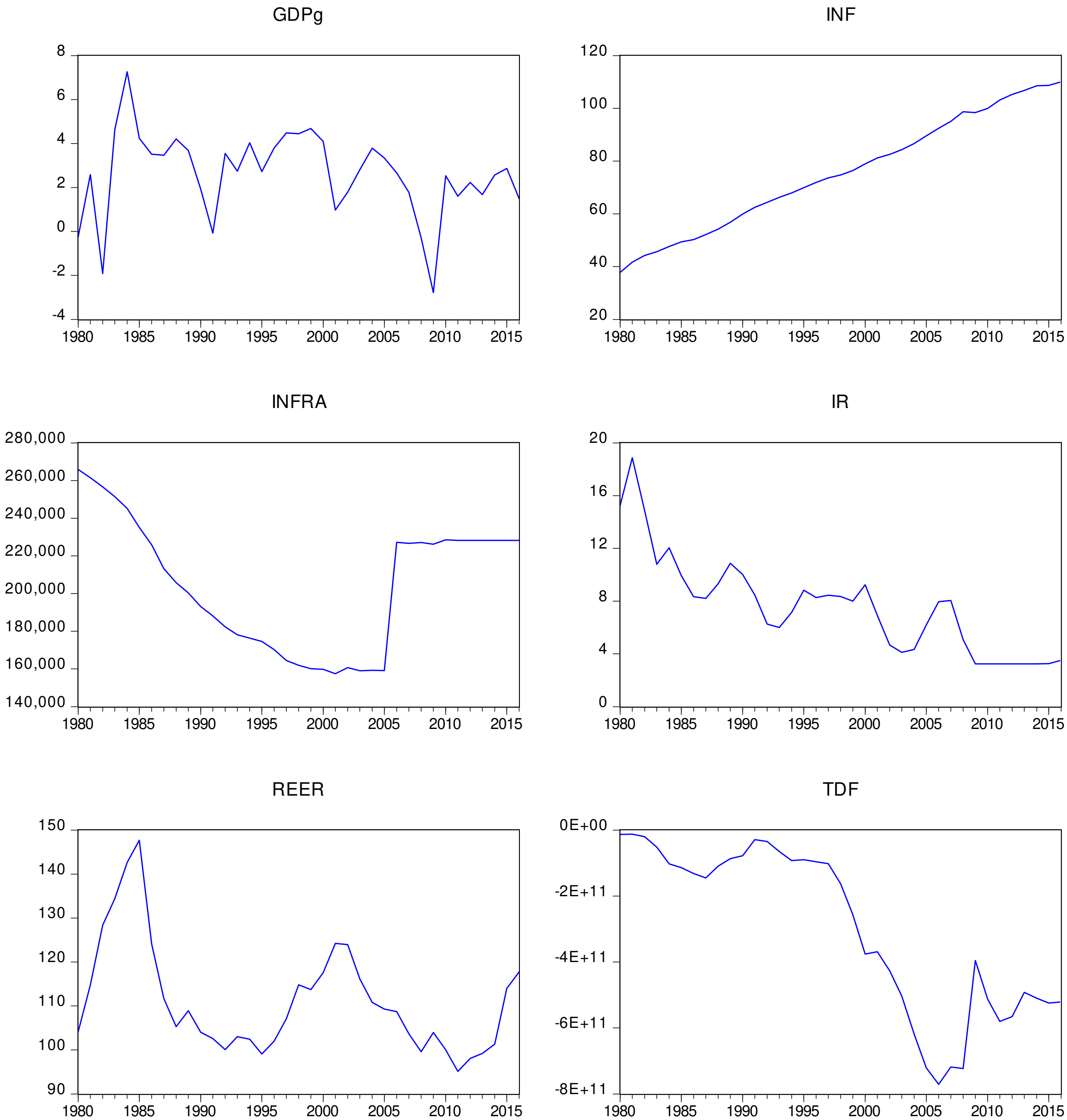
Table 6: Pairwise Granger Causality Test

Null Hypothesis	F- Statistic	Prob
REER does not Granger cause GDP	0.497	0.613
GDP does not Granger cause REER	1.732	0.194
INF does not Granger cause GDP	15.433	0.000***
GDP does not Granger cause INF	2.793	0.077*
IR does not Granger cause GDP	3.154	0.057*
GDP does not Granger cause IR	7.854	0.002***
INFRA does not Granger cause GDP	0.887	0.422
GDP does not Granger cause INFRA	4.571	0.019**
TDF does not Granger cause GDP	0.875	0.427
GDP does not Granger cause TDF	1.433	0.255
INF does not Granger cause REER	1.602	0.218
REER does not Granger cause INF	1.799	0.183
IR does not Granger cause REER	0.949	0.398
REER does not Granger cause IR	0.957	0.395
INFRA does not Granger cause REER	2.427	0.105
REER does not Granger cause INFRA	0.775	0.469
INFRA does not Granger cause REER	2.427	0.105
REER does not Granger cause INFRA	0.775	0.470
TDF does not Granger cause REER	2.532	0.096*
REER does not Granger cause TDF	4.263	0.023**
IR does not Granger cause INF	4.367	0.022**
INF does not Granger cause IR	12.859	0.000***
INFRA does not Granger cause INF	1.319	0.282
INF does not Granger cause INFRA	9.715	0.000***
TDF does not Granger cause INF	1.146	0.332
INF does not Granger cause TDF	1.320	0.282
INFRA does not Granger cause IR	7.167	0.003***
IR does not Granger cause INFRA	3.138	0.058*
TDF does not Granger cause IR	1.011	0.376
IR does not Granger cause TDF	1.531	0.232
TDF does not Granger cause INFRA	0.397	0.676
TDF does not Granger cause INFRA	3.915	0.031**

Appendix 1: Results of the Impulse Response



Appendix A: Plot of variables in Levels



Appendix b: Plot of variables in First Differenced