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Estimating the Railway Kuznet Curve for High Income Nations-A GMM Approach for three Pollution Indicators

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Abstract: *Railway transportation is still considered a marker of economic growth,but rarely isthe cost of environmental damages taken into account. The purpose of this study is to investigate the "Railway Kuznet Curve" in context of three key pollutants:Carbon dioxide emissions, Nitrous oxide emissions and Methane emissions, for 37 High income nations during 1990 to 2017. The econometric results of Panel GMM shows that there existsa "U shape" Railway Kuznet curve for carbon dioxide and methane emissions, indicating increasing level of pollution;while nitrous oxide emissions exhibit the "inverted U shape curve", validating the Railway Kuznet curve. The Pairwise DumitrescuHurlin Panel Causality shows a bidirectional relation of nitrous and methane emissions and unidirectional association of CO2 emissions to railway transportation. The diagnostic test of ARCH-effect and serial correlation shows homoscedasticity and no autocorrelation along with CUSUM test that shows stability of all the three models. Our econometric analysis suggests that developed nations should focus on exploiting renewable energy resources while adopting fuel-saving traveler and freight technologies, including hybrid switch trains and hydrogen-powered steam engines,in order to cut diesel consumption. Significance/novelty of the Study: This analysis has developed a novel contribution in literature by rational analysis for existence of Railways Transportation Kuznet curve hypotheses in the perspective of carbon, methane and nitrous oxide. Hence a wide-range analysis was carried out at panel data incorporating other key influential variables affecting environment such as trade, economic growth, population, energy consumption and FDI, which hadnot been carried out in previous studies. All the previous studies were carried out either on few countries or for selective years considering certain variables only in the context of CO_2 but current study is conducted on panel data for three different prominent environment degrading indicators (CO_2, N_2O, and CH4) one by one.*

Keywords: *Railway Transportation, Pollution emissions, Variance Decomposition*

INTRODUCTION

The transportation sector is plays a significant role in growth of an economy but at the same time, its environmental impacts cannot be underrated.

In spite of the efforts to make the automobiles more energy efficient; carbon dioxide, nitrogen dioxide and particulate matter emitted by these automobiles, nonetheless, contribute to the pollution.

Transportation conjures a diverse image of connectivity, leisure, recreation, business productivity, social contact and cultural exchange. Yet, it is a critical challenge to the environment. It derives economic growth by enhancing mobility of resources. It is an instrument of globalization, as it integrates economic, social, political and cultural activities. On the other hand, it threatens to destroy the environment. (Bissell & Fuller, 2017).

Nonetheless not as prevalent as the automobile, rail remains to be an imperative means of transportation for both passengers and cargo. Railway is considered as exorbitant equally at technical and infrastructural level; still, in developed nations, railway is the most efficient mode of transportation. Even so railway system is still keen on lowering the detritus emissions (Chapman, 2007; Scholten and Kunneke, 2016).

The railway operations and constructions have serious implications for environment. Particulate matter (PM10) and nitrogen oxides exposure are a big health hazard. The emissions have increased by 34% and ozone depletion substances by 40% (Ahn et al., 2010). Nevertheless, local air pollution, specifically in transportation, remains a main hazard. New burning technologies, efficient conduction systems and exhaust after-treatment can ensure that rail diesel power can be eco-friendly in the future than the road (Nithyanandan, 2017).

In this regard, railway transportation in context of pollution emission is analyzed based on the theory of Environmental Kuznets Curve (EKC). This hypothesis posits how per capita???? effects the environmental degradation at different stages in economic growth. This argues that a reduction in environmental degradation arises from economic growth as nations become wealthier and per capita income rises (Sarigiannidou and Palivos, 2012). The transportation as a railway mode in case of developed nations explicitly depicts the efficient mode because of electrification and advanced technologies. On the contrary,many studies show the significant GHG emissions by transport sector in developed nations. The below pie chart shows the emissions and sources of emissions only in US (USEPA, 2015).

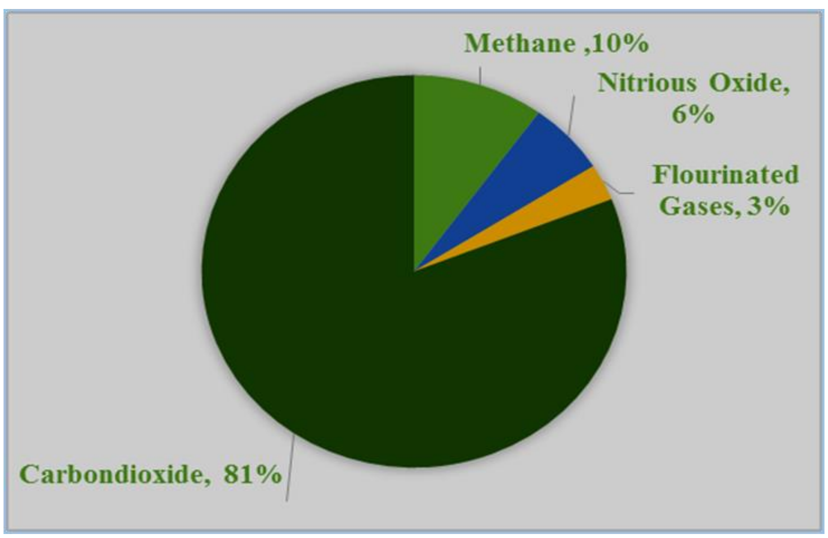

Figure1: Overview of Greenhouse Gases and Sources of Emissions (Source: USEPA- Inventory GHG Emissions.)

Moving towards the emissions by trade openness and related FDI, there can be seen diversity of association with the debris emissions.

Higher internalization, trade and FDI leads to an increment in more efficient market-based instruments and advanced infrastructure that reduce the negative externalities of transport and improve impartiality between modes.

. The inward FDI and trade are the crucial factors increasing the economic growth and productivity by providing high skill labor, technology transfer, research and development, finance, infrastructure, capital, export promotion, and market access (Acharyya, 2009). At one node, developed nations might reduce environmental degradation by adopting environmental policies, financial liberalization, FDI and trade that attract higher level of R&D related improvement in environmental quality (Tamazian, 2009). The technology is closely related to the trade openness as this phenomenon contemplates that trade will bring research and development that will decrease the environmental degradation (Katircioglu&Taspinar, 2017).

Moreover, population is the significant aspect in increasing environmental degradation by depleting the natural resources as well as increasing demands for energy and fuel for earning and livelihood for their survival (Nagdeve, 2007). Population growth and per capita income directly influence the environmental quality showing controversial debates. Population growth with high per capita income might reduce the environmental degradation by investing in the R&D to improve environmental quality and adoption of policies.Whereas, the higher growth of population with low per capita income increases poverty, and can severely worsen both the economy and the environment (Omri at al., 2015). The increase in population leads to the increase in energy demands that greatly emit high amount to waste, thus causing environmental damage. Summing up, transportation is interlinked with the population, trade, FDI, economic growth, and energy demand that collectively increases the environmental degradation.

Review of Literature:

The various studies mentioned below show different variables for diverse nations limited to the specified traditional analysis. Canas et al., (2003) studied the relationship between direct material input and income per capita during 1960 to 1998 for 16 industrialized countries. This paper examined the analytical value to the "dematerialization" since direct material input (DMI) per capita as the dependent variable in empirical implication of environmental Kuznets curve (EKC) and is gross domestic product per capita as an explanatory variable. By using panel data for the quadratic and cubic versions of EKC, the intensity of material consumption first increases but eventually starts exhibiting a decreasing trend after a certain income threshold was reached. The results showed a strong and robust support for both quadratic and cubic EKC relationships between material input and income in industrialized economies. The study for the existence of EKC also reveals that an increase of material used in low-income levels may be interconnected with responses to infrastructural needs, materials categories, evolution in economic structural change and share of the service sector contribution.

Kenworthy (2003) attempted to study the relationship between greenhouse gasses and transport energy in urban passenger transport system. The sample of 84 cities used in the research included cities from USA, Australia, Canada, Western Europe, high income Asia, Eastern Europe, the Middle East, Africa, low income Asia, Latin America and China. This study examined the CO2 emissions in contrast to other variables such as population density, transport infrastructure, public transport and non-motorized mode use. The econometric results implied that transport energy use and greenhouse gas emissions can be linked directly to the extent and quality of public transportation system. In relation to CO2 emissions, the USA is leading the way, followed by Australian and Canadian cities, while Chinese cities are at the lowest. Finally, this analysis suggests that in order to cut down greenhouse gas emissions, better quality transport system should be introduced, and people should consider alternate modes of transportation which are fuel efficient.

Colella*et al.,* (2005) tried to analyze the effects of changing fossil-fuel on-road vehicles (FFOV) to hydrogen fuel cell vehicles (HFCV) on environment i.e. air pollution and global climate. The study is based on US EPA's National Emission Inventory. The methodology called Life-cycle assessment (LCA) on alternative fuel supply has been used. The econometric results imply that all HFCVs are a source of reducing net air pollution emission. In addition, it may also reduce the global warming impact, greenhouse gasses and pollutant particles. Thus, the study suggests that hydrogen is not only an efficient means for transport; it will also lead to reduction in environmental degradation.

Norman *et al.,* (2006) studied the relationship between residential densities (i.e., population), energy use and greenhouse gas emissions. The study was conducted in Toronto city, US. The economic variables considered in the study were building operations, construction materials and transportation. By using the technique of economic input-output life-cycle assessment (EIO-LCA) the results showed that urban development plays a key role in GHG emissions and in turn, environmental degradation. Low density suburban development is more GHG producing as compared to high density city core development. Thus, in order to minimize GHG, efforts should be made in transportation in suburban development, while in order to minimize energy usage the focus should be on building materials.

Von Blottnitz and Curran (2007) assessed bio-ethanol as a transportation fuel with regard to environmental life along with net energy and greenhouse gas. The study was conducted on 47 published assessments comparing bio-ethanol and conventional fossil fuel. The study used life-cycle approach for comparison. The results of this research concluded that regarding energy and greenhouse gasses, bio-ethanol has more advantages because of its time and energy efficiency. But its production has other environmental hazards such as acidification, ecological toxicity and human toxicity. Due to increasing transportation usage, bio-ethanol is favorable as a resource. Most recent literatures are enlisted in the table below, that shows different studies in perspective of environmental pollution and other economic variables.

Table 1: Environmental Pollution and Related Economic Variables

Study	Country	Time Frame	Methodology	Results[1]
Oh and Bhuyan (2018)	Bangladesh	1975 - 2013	ARDL bound Test	CO2 to EC(+), PD(+)
Mikayilov et al., (2018)	Azerbaijan	1992-2013	ARDL to Cointegration	EG to CO2 emissions(+)
Ilham (2018)	8 ASEAN's Nations	2004-2013	Simultaneous Equation Model	CO2 to GDP, EC, TR, Economic development (+), EC to GDP(+), ED(-)
Rafindadi et al ., (2018)	GCC nations	1990- 2014	Pooled Mean Group	ED to FDI, EC(+)
Mitic et al., (2017)	17 different nations	1997-2017	DOLS &MOLS	GDP to CO2 (35%)
Sinha et al., (2017)	N-11 Nations	1990-2015	Cointegration	N-shaped EKC
Shahzad et al., (2017)	Pakistan	2003-2015	ARDL to Cointegration	Trade to CO2 (0.24%), Financial Development to CO2 (0,087%),
Zheng and Sheng (2017)	China	1997-2009	GMM	FDI to CO2(+)
Jamel and Makatouf (2017)	40 European Nations	1985-2014	OLS	Bi-direction EG to CO2, EKC exist
Li et al ., (2016)	China	1996-2012	GMM and ARDL	CO2 to EC , TR(+)
Pazienza (2015)	30 OECD nations	1981-2005	Fixed Effect and Random Effect	CO2 to FDI(+)
Al-Mulali and Uzturk (2015)	MENA Region	1996-2012	Panel Pedroni Cointegration	CO2 to EC, TR, Urbanization (+)

[1] ED: Environmental Degradation, EC: Energy Consumption, PD: Population Density, EG: Economic Growth , TR: Trade openness

			and FMOLS	
Akomolafe et al., (2015)	Nigeria	1990-2010	VECM	PHH and EKC exist, Short run(+) and Long run(-)
Hassaballa (2013)	8 Developing nations	1982-1992.	Fixed Effect and Random Effect	FDI does not affect environment.
Mehmood et al., (2012)	Pakistan	1972-2005	ARDL &ECM	FDI to CO2(+)
Cristea et al., (2011)	Worldwide	1990-2010	Global Trade Analysis Project (GTAP)	33% emissions by trade transport 75% emissions by Manufacturing
Ozturk and Acaravci (2010)	Turkey	1968-2005	ARDL Bound Test	EKC not valid.
Acharyya (2009)	India	1980-2003	Cointegration Regression	GDP (86%), Urbanization (57%) GHG Emissions

Significance of the Study:

This analysis has developed a novel contribution in the literature by rational analysis for the existence of Railways Transportation Kuznet curve hypotheses in the perspective of carbon, methane and nitrous oxide. Railway transportation from energy point of view is naive feature of this research in context of three striking environmental degrading indicators. Hence a wide-range analysis is carried out at panel data incorporating other key influential variables affecting environment such as trade, economic growth, population, energy consumption and FDI which has not been carried out in previous studies.

All the previous studies were either carried out on few countries or for selective years considering certain variables (energy consumption, growth or population) only in context of CO_2, but the current study is conducted on panel data for three different prominent environment degrading indicators (CO_2, N_2O, and CH4) one by one.

Objectives of the study:

- To explore the existence of Railway Transportation Kuznet curve for high transition economies in the context of CO2.
- To investigate Railway Transportation Kuznet curve for higher transition economies in perspective of N2O.
- To examine Railway Transportation Kuznet curve for higher transition economies in the context of CH4.

Hypotheses of the Study:

- H_1: There exists Railway Kuznet Curve to carbon dioxide under different explanatory factors in panel high income countries.
- H_2: There exists Railway Kuznet Curve to nitrous oxide emissions under different explanatory factors in panel high income countries.
- H_3: There exists Railway Kuznet Curve to methane emission under different explanatory factors in panel high income countries.

Data Source and Methodology:

Data Source:

The data has been taken from World Bank (WB, 2018) and World Development Indicator (WDI, 2018). Based on the World Bank income the division of the total availability of data for high income nations are 47 out of which missing data for railways is 10. Therefore, 37 high income nations have been selected.

Conceptual Framework:

The American Economist Simon Smith Kuznet proposed the inverted U-Shaped relationship between environmental indicators and economic growth during 1955 and 1963. The shapes of EKC may vary according to the nature of development and pollution indicators like inverted "U" shape, "U" shape and "N" shape etc. The most consistent thought of classical school is concerned with the long run consequences of economic growth which may impart positive and negative impact on the nations. With this regard the EKC theory supports the current analysis such as; economic growth by transportation and pollution emissions as environmental indicators. The debate of EKC continues to the other pollution indicators and level of economic development of diverse income based nations. Hence, pollution-income relationship as EKC depicts that the environmental quality and economic growth tends to get worsen until a certain level of income recover environment quality. However, the economic growth can be enhanced by improving technology, advanced industrializations process, mechanized agriculture, skilled labors along with encompassing research and development (Adenle*et al.,* 2017). Endogenous growth model also encompasses the interaction between trade, economic growth, and the environment. Transportation systems are associated with an extensive range of environmental contemplations at all geographical scales, from the international to the native level. The nature of these environmental impressions is connected to the transport means themselves, their energy stream systems, their releases and the infrastructures over which they function (Ford, et al., 2017).

Econometric Model:

The econometric model based on the theory of EKC is formulated as RKC (Railway Kuznet Curve) in context of CO2, N2O and CH4 that is exhibited without taking log form because FDI has negative values.

$$(CO2)_{it} = \alpha_0 + \alpha_1 (PCGDP)_{it} + \alpha_2 (RPC)_{it} + \alpha_3 (RPC)^2_{it} + \alpha_4 (RTG)_{it} + \alpha_5 (RTG)^2_{it} + \alpha_6 (FDI)_{it} + \alpha_7 (TOP)_{it} + \alpha_8 (ED)_{it} + \alpha_9 (PG)_{it} + \varepsilon_{it}$$

$$(N2O)_{it} = \alpha_0 + \alpha_1 (PCGDP)_{it} + \alpha_2 (RPC)_{it} + \alpha_3 (RPC)^2_{it} + \alpha_4 (RTG)_{it} + \alpha_5 (RTG)^2_{it} + \alpha_6 (FDI)_{it} + \alpha_7 (TOP)_{it} + \alpha_8 (ED)_{it} + \alpha_9 (PG)_{it} + \varepsilon_{it}$$

$$(CH4)_{it} = \alpha_0 + \alpha_1 (PCGDP)_{it} + \alpha_2 (RPC)_{it} + \alpha_3 (RPC)^2_{it} + \alpha_4 (RTG)_{it} + \alpha_5 (RTG)^2_{it} + \alpha_6 (FDI)_{it} + \alpha_7 (TOP)_{it} + \alpha_8 (ED)_{it} + \alpha_9 (PG)_{it} + \varepsilon_{it}$$

"i" shows high income nations, "t" is time period of 1990 to 2017. The dependent variables as degrading emissions are CO2 emissions from transport *"(% of total fuel combustion)",* Nitrous oxide and Methane emissions as *"(thousand metric tons of CO2 equivalent)".* While dependent variables are: Per capita Income: PCGDP *(Constant 2010 US$)", RTG/RGT (*Railways *Goods transported (million ton-km)), RPC (*Railways *passengers carried (million passenger-km)), ED (Energy Demand (kg of oil equivalent per capita)), F*DI (Inflows: *net (BoP, current US $), TOP (*Trade openness: "*Trade (% of GDP))* and*PG (*Population Growth: "*Population density (people per sq. km of land area)).*

Results and Discussion:

Table 2: Descriptive Statistics of the Pollutants and the related Economic Variables

Statistics	CO2	CH4	N2O	RPC	RGT	ED	GDP	TOP	PG	FDI
Mean	27.599	15362	3313	17673	80472	4166	34375	95	296	24100
Median	25.876	2040.43	646.988	3687	8385	3772.881	33682.240	74.131	102.492	60200
Maximum	69.756	252381	82671.320	260014	2839124	12087	111968	441.604	8010.669	7.341
Minimum	4.503	98.685	8.349	8.465	13.490	723.846	5140.528	16.012	2.221	-4.391
Skewness	0.772	4.773	5.790	4.392	5.926	1.112	0.974	2.449	5.944	5.346
Kurtosis	3.975	26.725	36.123	23.876	37.611	4.430	4.175	10.189	37.872	41.804
Jarque-Bera	144	28230	53148	22143	57774	301	223	3266	58593	69931
Probability	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Observations	1036	1036	1036	1036	1036	1036	1036	1036	1036	1036

Descriptive Statistics:

The mean value of CO2 emission is (27.59) % of total fuel combustion, methane emission is (15362) thousand metric tons of CO_2 equivalent , nitrous oxide emission is (3313) thousand metric tons of CO_2 equivalent, railway passenger carried is (17673) million passenger-km, railway goods transported is (80471) million ton-km, energy demand is (4166) kg of oil equivalent per capita, GDP is (34375) Constant 2010 US$, trade openness is (95) % of GDP, population growth is (296) people per sq. km of land area and FDI is (24100) BOP, current US$. The maximum of CO2 emission is (69.756) % of total fuel combustion, methane emission is (252381.8), nitrous oxide emission is (82671.32). Skewness indicate to which to which extent the data is not symmetrical. The value of skewness of CO2 emission (0.772), methane emission (4.773), nitrous oxide emission (5.790), railway passenger carried (4.392), railway good transported (5.925), energy demand (1.112), GDP (0.974), trade openness (2.448), population growth (5.944), FDI (5.345) are positively skewed. Kurtosis indicate the peakeness of the probability distribution. The value of CO2 emission (3.947), methaneemission (26.724), nitrous oxide emission (36.122), railway passenger carried (23.875), railway good transported (37.611), energy demand (4.430), GDP(4.174), trade openness(10.188), population growth(37.871), FDI (41.803). Jarque -bera measure the normality of the distribution. The value of CO2 emission is (144.024), methane emission is (28230.94), nitrous oxide emission is (53148.02), railway passenger carried is (22143.33), railway good transported is (57774.97), energy demand is (301.899), GDP is (223.547), trade openness is (3266.206), population growth is (58593.93), FDI is (69931.65).

Correlation Analysis:

Table 3: Correlation Matrix Showing the Pollutants and the Related Economic Variables

Correlation										
Probability	**CO2**	**CH4**	**N2O**	**RPC**	**RGT**	**ED**	**GDP**	**TOP**	**PG**	**FDI**
CO2	1.000									
CH4	-0.007	1.000								
	0.832	-----								
N2O	0.019	0.938	1.000							
	0.532	0.000	-----							
RPC	-0.126	-0.003	0.075	1.000						
	0.000	0.925	0.016	-----						
RGT	0.054	0.923	0.951	-0.023	1.000					
	0.083	0.000	0.000	0.467	-----					
ED	0.004	0.372	0.306	-0.078	0.311	1.000				
	0.893	0.000	0.000	0.012	0.000	-----				

GDP	0.402	0.080	0.090	0.081	0.103	0.594	1.000			
	0.000	0.010	0.004	0.009	0.001	0.000	-----			
TOP	0.011	-0.253	-0.233	-0.266	-0.190	0.222	0.254	1.000		
	0.714	0.000	0.000	0.000	0.000	0.000	0.000	-----		
PG	-0.221	-0.081	-0.058	-0.015	-0.052	0.073	0.052	0.641	1.000	
	0.000	0.009	0.064	0.633	0.094	0.019	0.096	0.000	-----	
FDI	0.016	0.503	0.490	0.047	0.568	0.191	0.209	-0.021	0.043	1.000
	0.606	0.000	0.000	0.128	0.000	0.000	0.000	0.498	0.168	-----

The relationship of CO2 emission with methane emission (-0.006), railway passenger carried (-0.125), population growth (-0.220) have negative and weak while CO2 emission with nitrous oxide emission (0.019), railway good transported (0.053), energy demand (0.004), GDP (0.402), trade openness (0.402), and FDI (0.016) have positive but weak relationship. The association of Methane emission with nitrous oxide (0.938), railway good transported (0.923), have strong positive relationship. Methane emission with railway passenger carried (-0.002), trade openness (-0.252) and population growth (-0.080) have negative weak relationship. While methane emission with energy demand (0.372), GDP (0.079) and FDI (0.503) have positive relationship. The relationship of nitrous oxide with railway good transported (0.951) have strong positive relationship and nitrous oxide with trade openness (-0.233), population growth (-0.057) have negative weak relationship and railway passenger carried (0.075), energy demand (0.305), GDP (0.090) and FDI (0.490) have weak relationship. Trade openness (-0.218) and population growth (-0.052) have weak relationship. The relationship of railway passenger carried with railway good transported (-0.022), energy demand (-0.077), trade openness (-2.66) and population growth (-0.014) have negative weak relationship. While railway passenger carried with FDI (0.047) and GDP (0.081) have weak relationship. The relationship of railway good transported with energy demand (0.311), GDP (0.103), FDI (0.568) have positive relationship while railway good transported with population growth (-0.051) and trade openness (-0.189) have negative relationship. The relationship of energy demand with GDP (0.594), trade openness (0.222), population growth (0.073) and FDI (0.190) have positive relationship. The relationship of GDP with trade openness (0.254), population growth (0.057) and FDI (0.208) have positive weak relationship. The relationship of trade openness with population growth (0.641) has positive relationship while FDI (-0.021) has negative relationship. There is weak association between population growth and FDI (0.042).

Panel Unit Root Test Summary:

The panel data is treated firstly by the panel unit root test summary as an extension of the Univariate unit root test. The LLC test is based on the pooled panel data as follows (Levin and Lin 1992).

$yit = \rho yi\, t{-}1 + \alpha 0 + \sigma t + \sigma i + \theta t + \varepsilon it$

where, ρ, 0, σ are coefficients, αi is individual specific effect, θt is time specific effect. Secondly, ADF test is applied to each individual series and normalized the disturbance.

The ADF model is expressed as:

$$\Delta yit = \rho iyit - 1 + \sum_{j=1}^{pi} \delta ij \Delta yi, t - j + \alpha i + \varepsilon it$$

The null hypothesis and the alternative hypothesis are expressed as:

$$H_0 : \rho_i = 0$$
$$H_A : \rho_i < 0$$

The null hypothesis of unit root test is that all series are non-stationary process under the alternative hypothesis that fraction of the series in the panel are assumed to be stationary. The LLC, IPS, ADF and PP Fisher unit root test shows that all the series at first difference are integrated.

Table 4: LLC, IPS, ADF and PP Fisher Unit Root Tests of the Panel Data

Variables	Unit Root Methods	High Income Transition											
		Level		1st Difference		Level		1st Difference		Level		1st Difference	
		Stats.	**Prob.**	**Stats**	**Prob.**	**Stats.**	**Prob.**	**Stats.**	**Prob.**	**Stats.**	**Prob.**	**Stats.**	**Prob.**
CO2, N2O, CH4	LLC	1.299	0.903	-9.52	0.000	-1.82	0.0347	-7.29	0.000	0.304	0.6196	-11.00	0.000
	IPS	5.1260	1.000	-14.83	0.000	-0.76	0.2222	-9.59	0.000	2.662	0.9961	-12.17	0.000
	ADF	37.634	0.999	363.1	0.000	116.9	0.0011	245.3	0.000	77.22	0.3759	301.87	0.000
	PPF	41.592	0.999	675.2	0.000	132.5	0.0000	484.7	0.000	84.67	0.1860	470.84	0.000
RPC, RGT, FDI	LLC	0.0670	0.526	-14.46	0.000	2.518	0.9941	-83.16	0.000	-2.15	0.0157	-13.99	0.000
	IPS	-0.61	0.270	-15.60	0.000	2.836	0.9977	-27.76	0.000	-3.39	0.0003	-21.12	0.000
	ADF	116.83	0.001	374.27	0.000	59.08	0.8968	371.5	0.000	113.3	0.0022	519.75	0.000
	PPF	161.39	0.000	577.8	0.000	61.25	0.8553	600.1	0.000	199.6	0.0000	923.66	0.000
TOP, GDP, ED	LLC	-1.33	0.092	-16.08	0.000	-2.81	0.0025	-11.81	0.000	-1.27	0.1022	-10.69	0.000
	IPS	1.0125	0.844	-15.84	0.000	3.643	0.9999	-12.83	0.000	-0.53	0.2987	-13.30	0.000
	ADF	60.874	0.863	380.10	0.000	35.89	0.9999	308.5	0.000	120.0	0.0006	318.63	0.000
	PPF	51.004	0.981	615.30	0.000	31.34	1.0000	423.3	0.000	111.8	0.0030	652.26	0.000
PG	LLC	0.9293	0.823	-4.64	0.000	LLC:	Levin, Lin & Chu t*						
	IPS	7.5112	1.000	-5.01	0.000	IPS	Im, Pesaran and Shin W-stat						
	ADF	67.654	0.685	152.39	0.000	ADF	ADF-Fisher Chi-square						
	PPF	101.18	0.019	170.41	0.000	PPF	PP-Fisher Chi-square						

Panel Cointegration:

After unit root, Panel Cointegration is applied in order to analyze the long run cointegration among the series of three models separately. The series are integrated on two statistics based on Fisher Statistics such that max-eigen test and trace test. All the variables show significant probability statistics by either test. The null hypothesis states that there is no long run cointegration among the series that is rejected at 5% probability against the alternative hypothesis of long run cointegration. The estimated panel fisher cointegration shows that considered variables are connected in long run cointegration.

Table 5: Analysis of Long-run Cointegration in the Three Models

Independent Variable	**GDP, RPC, RPC²,RGT, RGT², FDI, TOP,ED, PG**											
Dependent Variable	**CO2**				**N2O**					**CH4**		
Hypothesized No. of CE(s)	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stats.*(from max-eigen test)**	**Prob.**	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stats.*(from max-eigen test)**	**Prob.**	**Fisher Stat.* (from trace test)**	**Prob.**	**Fisher Stats. (from max-eigen test)**	**Prob.**
None	48.52	0.9765	48.52	0.9765	48.52	0.9765	48.52	0.9765	48.52	0.9765	48.52	0.9765
At most 1	47.13	0.9837	65.55	0.6283	44.36	0.9929	99.62	0.0115	44.36	0.9929	99.62	0.0115
At most 2	30.50	1.0000	270.0	0.0000	31.88	1.0000	252.9	0.0000	23.57	1.0000	355.1	0.0000

At most 3	8.318	1.0000	542.5	0.0000	1.386	1.0000	627.7	0.0000	6.931	1.0000	559.6	0.0000
At most 4	644.7	0.0000	644.7	0.0000	644.7	0.0000	644.7	0.0000	644.7	0.0000	644.7	0.0000
At most 5	1538.	0.0000	943.2	0.0000	1551.	0.0000	957.4	0.0000	1549.	0.0000	906.2	0.0000
At most 6	1018.	0.0000	568.9	0.0000	1019.	0.0000	539.4	0.0000	1020.	0.0000	550.0	0.0000
At most 7	581.4	0.0000	348.6	0.0000	597.6	0.0000	378.4	0.0000	590.0	0.0000	383.9	0.0000
At most 8	335.5	0.0000	264.6	0.0000	320.2	0.0000	257.9	0.0000	310.1	0.0000	231.6	0.0000
At most 9	192.7	0.0000	192.7	0.0000	185.0	0.0000	185.0	0.0000	214.6	0.0000	214.6	0.0000

Correlated Random Effects - Hausman Test:

Table 6: Application of Hausman Test to decide between Fixed Effect and Random Effect

Dependent Variable	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.	Decision
CO2	61.366183	10	0.0000	Fixed Effect
N2O	52.659108	10	0.0000	Fixed Effect
CH4	29.048897	10	0.0012	Fixed Effect

Before applying the panel or dynamic GMM for the panel data, it was better to test the existence of the correlational random or fixed effect in the models. For this purpose,Hausman test was applied and significant probability values at 1 % indicated the rejection of null hypothesis that Random effect was better. Generally, all three models' results indicated the usage of fixed effect model. In the current literature of econometrics, the most widely circulated advance technique is GMM that has explicit connection to other estimating methods which produces ``efficient" estimators. The accuracy and efficiency of finite sample size is examined by the variant of Arellano-Bond and the Blundell-Bond GMM estimations which considers the existence of heteroskedasticity due to dynamic nature of data along with endogenity (Kiviet et al., 2017). In this analysis GMM is applied to account for the dynamics in the model along with covering the issue of endogenity and heteroskedasticity. When there are changes in one explicative variable, they impact the dependent variable but it adjusts over time to that impact towards its long run equilibrium. GMM umbrellas OLS estimators, 2SLS and IV technique that is not only applicable to single equation but as a whole system of equations in case of panel data along with an extension to panel study. The dynamics of panel data is better handled by this technique by covering the cross section differences and by taking differenced lagged value as an instrument making the estimators consistent.

Panel GMM:

Table 7: Application of GMM to the Panel Data

Dependent variable	CO2		N2O		CH4	
Independent Variable	**Coefficient (Std. Error)**	**t-Statistic**	**Coefficient (Std. Error)**	**t-Statistic**	**Coefficient (Std. Error)**	**t-Statistic**
C	2.753* (0.992)	2.775202	1.0256* (0.051)	20.1098	0.969* (0.080)	12.1125
GDP	5.855* (1.9405)	3.017264	0.516* (0.0536)	9.626866	-0.046* (0.00935)	-4.91979
RPC	-5.796* (1.301)	-4.45503	1.069* (0.0423)	25.27187	-1.013* (0.061)	-16.6066
RPC2	3.641* (1.103)	3.300997	-2.071* (0.145)	-14.2759	4.7108** (2.481)	1.898751
RGT	-7.88* (2.811)	-2.80327	1.119* (0.411)	2.722628	-1.638*** (0.912)	-1.79605
RGT2	3.28* (0.687)	4.774381	-8.141* (0.976)	-8.34119	2.261* (0.324)	6.975309

FDI	-3.651** (1.911)	-1.91052	-1.72* (0.438)	-3.92694	4.0509** (1.629)	2.48674
TOP	0.095** (0.0417)	2.278177	0.2778 (0.193)	1.439378	-0.941* (0.135)	-6.97037
ED	-0.0346** (0.0184)	-1.88043	-0.0128** (0.006)	-2.13333	0.0974** (0.0504)	1.93254
PG	-0.0275* (0.00786)	-3.49873	0.0374 (0.053)	0.70566	-0.034* (0.0088)	-3.86364

In the first model where carbon dioxide is dependent variable shows the significant impact on environment by influential considered regressors. The GMM estimate of coefficient GDP depicts positive relation to carbon emission. It indicates that one unit increase in GDP leads to increase the carbon emission by 5.855 units that is significant at one percent. Similarly, trade openness leads to increase carbon emission by 0.095 percent.

In case of railways passenger and cargo, there exist 'U' shaped Railway Kuznet Curve. The econometric results showed that the first degree coefficient is negative. This is while second order coefficient of both Railway passenger and Railway Cargo is positive. The turning points of railway transportation for 'U' shape Curve was 0.796 and 1.201 for railway passenger and cargo respectively. This indicates that with the increase of Trade openness, economic growth and transportation by railway increase carbon emissions significantly. Results are consistent with the study of Cristea et al., (2013). Moreover, for energy demand and Population density decreases the one-unit increase in emission by -3.651, 0.034 & 0.027 units respectively for the selected time frame. The results were consistent with Jones and Kammen (2014).

In the second model where Nitrous oxide is dependent variable shows that one unit increase in per capita growth, Trade openness and Population growth increase the nitrous emission by 0.516, 0.2778 and 0.053 respectively. Consistency with the carbon emission, one-unit increase in FDI and Energy demand decreases the nitrous emission by 1.72 and 0.0374 units respectively. In case of railway passenger and Cargo the nitrous oxide validates the existence of inverted 'U' shape Railway Kuznet Curve. The turning points of railway passenger and cargo is.0.2580 and 0.0687respectively. The relations are consistent with the study of Zhang (2011).

In the third model for the case of methane emission, there exist significantly positive relation of FDI and Energy demand. The econometric results indicate that one unit increase in FDI and energy use increases the methane emission by 4.0506 and 0.0974 unit. While one unit increase in GDP, Trade openness and Population density decreases the methane emission by 0.046, 0.941 and -0.034 respectively. Finally, there exist 'U" shape railway Kuznet Curve for the methane emission. The turning points for the railway passenger and cargo is 0.1075 and 0.3622 respectively. The econometric results are consistent with Cole and McCoskey (2013). The below curves shows the basis of EKC for railway transportation in context of carbon dioxide emissions (U shape), nitrous oxide emissions (inverted U shape) and methane emissions (U shape) respectively.

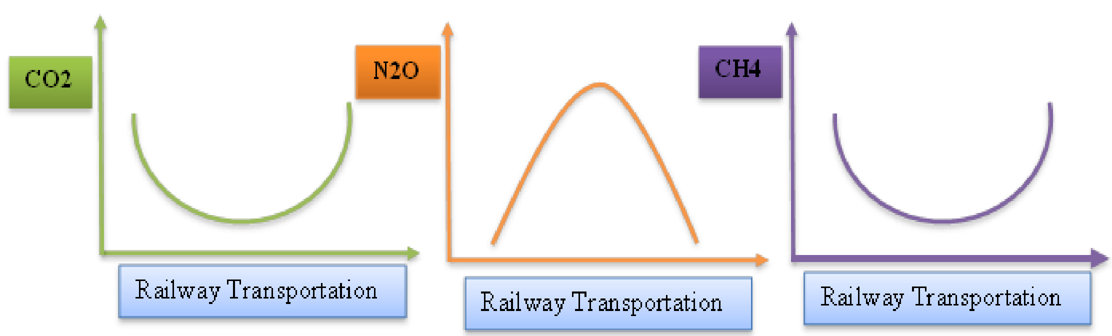

Figure 2: U-shape Curves for CO2 and CH4 and Inverted U-shaped Curve for N2O

Impulse Response Function:

Impulse responses show how a variable responds to a shock in the other variable initially and whether the effect of the shock persists or dies out quickly. The CO2 respond to population growth, energy demand and railway goods transportation positively and nearer to the mean position. The GDP has an increasing and diverging response from the average value while railway passenger transportation has a negative response to carbon emission. The response GDP to all the regressive is decreasing and away from mean position. Similarly, response of RGT to FDI is negative and diverging and all of the other variables have increasing drift. The response of RPC to trade openness is diverging from average position while energy demand and carbon emissions have positive increasing variation. The N2O responds a decreasing trend to energy demand and RPC while trade openness converges back to mean position after a minor decrease. The railway transportation response to the entire variables positively and later on diverging trend from the mean position. The response of CH4 to railway transportation is throughout increasing and diverging from average position while energy demand and FDI respond positively but converging trend. Finally, CH4 to trade openness shows decreasing and deviating position from the mean value. The below tables show the impulse response statistics for the next ten years.

Table 8: Ten Year Impulse Response Statistics for i) CO2, N2O and CH4

Period	D(CO2)	D(GDP)	D(RPC)	D(RPC2)	D(RGT)	D(RGT2)	D(FDI)	D(TOP)	D(ED)	D(PG)
1	1.884494	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	-0.07341	0.262602	0.008065	0.008520	-0.01832	0.037835	-0.05146	-0.00464	0.058195	0.041869
3	-0.19089	0.014705	-0.02577	0.051821	-0.03907	0.000511	0.010404	-0.08972	-0.0642	-0.10013
4	0.025196	-0.02213	-0.00592	-0.04386	-0.01444	-0.00041	3.05E-05	0.01492	0.014815	-0.01734
5	0.025793	0.020743	-0.03575	-0.01611	-0.0044	0.003623	0.010460	-0.00351	0.003397	-0.02306
6	-0.00343	0.002276	0.005017	-0.00925	-0.00061	0.002398	-0.00283	-0.00505	-0.0001	-0.0199
7	-0.00016	-0.00286	0.036001	0.030143	-0.00017	0.001410	-0.00031	-0.00302	0.001271	-0.01391
8	0.002476	-0.0016	0.038350	0.031406	0.000366	0.000301	0.000604	-0.00224	0.001354	-0.01047
9	0.001810	-0.00142	-0.00883	0.001323	0.000307	0.000134	-0.00042	-0.00183	0.000703	-0.00818
10	0.000136	-0.00176	-0.05444	-0.04089	-0.00015	-7.5305	-0.00065	-0.00094	-1.6905	-0.0064
Period	**D(N2O)**	**D(GDP)**	**D(RPC)**	**D(RPC2)**	**D(RGT)**	**D(RGT2)**	**D(FDI)**	**D(TOP)**	**D(ED)**	**D(PG)**
1	264.4010	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	99.09060	-2.67215	2.751741	0.805029	6.959331	3.809392	-10.0153	5.391665	-7.60268	-1.03871
3	147.1453	-3.3931	3.737595	-1.62315	-28.2887	-19.0168	-29.1848	7.862137	1.205673	3.411845
4	81.04964	-3.18733	0.182345	1.687319	-28.3932	-14.7112	-4.61501	4.387807	-2.52701	-0.14421
5	90.60269	-3.52345	1.543158	-2.44255	-29.1063	-14.5161	-8.15227	5.986746	0.582630	1.619103
6	62.99694	-3.2907	1.085173	0.172797	-20.9977	-8.3725	-3.60251	3.746944	-0.99845	0.484877
7	61.15590	-3.35708	3.626168	0.091900	-17.985	-7.32068	-5.24608	3.964971	0.026326	1.267804
8	47.24166	-2.77189	3.292812	1.961578	-14.2291	-5.32385	-3.38875	2.951891	-0.62127	0.884113
9	42.46835	-2.46474	1.795233	0.200647	-12.4844	-4.93126	-3.69786	2.767096	-0.24865	1.090269
10	34.34913	-2.05398	-1.21639	-1.42337	-10.4268	-3.99096	-2.68433	2.233149	-0.43784	0.859698
Period	**D(CH4)**	**D(GDP)**	**D(RPC)**	**D(RPC2)**	**D(RGT)**	**D(RGT2)**	**D(FDI)**	**D(TOP)**	**D(ED)**	**D(PG)**
1	1040.277	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	297.8727	-23.6133	12.25875	-21.8724	-57.4552	36.07296	16.82748	-2.02983	35.14110	2.016548

3	249.0928	-4.18725	134.6212	-97.164	48.12727	36.67329	30.46886	1.812466	10.76072	-6.51641
4	110.6044	-4.73524	100.3274	91.49649	29.26821	35.12220	7.864936	1.837187	6.318901	2.087044
5	67.12130	-3.24581	106.4651	22.96710	27.05955	15.52733	-8.56847	-0.58806	7.660243	4.353936
6	30.33111	-2.14707	-39.9278	-10.4666	11.79339	8.794599	0.322773	0.540871	2.117387	3.492476
7	16.93998	-1.61709	-113.991	-108.037	6.069990	2.502965	-2.62356	1.715080	0.474777	4.028610
8	9.989873	-1.96376	-78.1012	-74.0679	2.071809	1.551735	0.703581	2.520146	-1.35271	3.081130
9	8.293584	-0.68187	77.48564	36.29460	2.161247	0.814820	1.443469	1.564900	0.025379	2.754918
10	4.791898	1.235329	174.0853	136.8641	2.786918	1.017439	1.294359	-0.68191	1.825147	2.163781

Variance Decomposition Effect:

Forecast error variance decompositions point out what proportion of the variation in a variable can be explained by the changes in another variable in the same VAR system. The self-shock in carbon emission respond to a minor decline from 97% to 96%. However, in the first quarter the response from dependent variable carbon dioxide to independent series is positive e.g. 1.89% to GDP 0.001% in railway passenger, 0.0019% in railway cargo, 0.072% in FDI, 0.0993% in energy use and 0.048% in population density. In the 5th quarter all the shocks moved positively showing a positive trend from previous years. There are minor fluctuations in long run shocks after 8th quarter and finally railway transport respond to 0.21% as passenger carried and 0.23% of railway cargo transport that is significantly increasing yearly.

Table 9: Variance Decomposition Effects for i) CO2, ii) N2O and iii) CH4

Period	S.E.	D(CO2)	D(GDP)	D(RPC)	D(RPC2)	D(RGT)	D(RGT2)	D(FDI)	D(TOP)	D(ED)	D(PG)
1	1.884494	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	1.906667	97.83588	1.896904	0.001789	0.001997	0.009230	0.039377	0.072853	0.000593	0.093158	0.048220
3	1.923335	97.13257	1.870015	0.019710	0.074558	0.050333	0.038704	0.074522	0.218170	0.202984	0.318434
4	1.924383	97.04389	1.881200	0.020636	0.126426	0.055906	0.038667	0.074441	0.223944	0.208689	0.326202
5	1.925249	96.97464	1.891118	0.055096	0.133311	0.056378	0.038986	0.077326	0.224075	0.208813	0.340255
6	1.925395	96.96022	1.890970	0.055766	0.135601	0.056380	0.039135	0.077530	0.224728	0.208781	0.350890
7	1.926023	96.89699	1.889957	0.090668	0.160006	0.056344	0.039163	0.077482	0.224827	0.208689	0.355875
8	1.926693	96.82974	1.888711	0.130224	0.186466	0.056308	0.039138	0.077438	0.224806	0.208593	0.358578
9	1.926734	96.82575	1.888686	0.132320	0.186505	0.056308	0.039137	0.077440	0.224887	0.208598	0.360366
10	1.927948	96.70382	1.886391	0.211888	0.231244	0.056238	0.039088	0.077354	0.224628	0.208335	0.361015
Period	S.E.	D(N2O)	D(GDP)	D(RPC)	D(RPC2)	D(RGT)	D(RGT2)	D(FDI)	D(TOP)	D(ED)	D(PG)
1	264.4010	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	282.8310	99.66677	0.008926	0.009466	0.000810	0.060545	0.018141	0.125394	0.036341	0.072257	0.001349
3	322.1208	97.70317	0.017977	0.020761	0.003164	0.817912	0.362514	0.917544	0.087588	0.057106	0.012258
4	333.7865	96.88923	0.025861	0.019365	0.005502	1.485329	0.531867	0.873645	0.098854	0.058916	0.011435
5	347.5718	96.15108	0.034127	0.019830	0.010013	2.071115	0.664940	0.860732	0.120836	0.054616	0.012716
6	354.0142	95.85000	0.041536	0.020055	0.009675	2.348224	0.696892	0.840045	0.127680	0.053442	0.012445
7	359.8784	95.63953	0.048896	0.029559	0.009369	2.522072	0.715745	0.834142	0.135692	0.051715	0.013284
8	363.3439	95.51435	0.053787	0.037211	0.012106	2.627554	0.723626	0.827004	0.139716	0.051025	0.013624
9	366.1072	95.42356	0.057511	0.039056	0.011954	2.704324	0.730887	0.824769	0.143328	0.050304	0.014306
10	367.9128	95.36088	0.060064	0.039767	0.013333	2.758163	0.735497	0.822017	0.145608	0.049953	0.014712

Period	S.E.	D(CH4)	D(GDP)	D(RPC)	D(RPC2)	D(RGT)	D(RGT2)	D(FDI)	D(TOP)	D(ED)	D(PG)
1	1040.277	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
2	1085.458	99.37916	0.047325	0.012755	0.040604	0.280177	0.110443	0.024033	0.000350	0.104810	0.000345
3	1128.095	96.88455	0.045193	1.435892	0.779448	0.441407	0.207936	0.095200	0.000582	0.106136	0.003656
4	1142.581	95.38055	0.045772	2.170732	1.401070	0.495902	0.297188	0.097540	0.000826	0.106521	0.003898
5	1150.215	94.45923	0.045962	2.998770	1.422405	0.544687	0.311480	0.101799	0.000841	0.109547	0.005279
6	1151.458	94.32473	0.046211	3.112539	1.427597	0.554002	0.316641	0.101587	0.000861	0.109649	0.006188
7	1162.274	92.59861	0.045548	4.016773	2.265182	0.546466	0.311239	0.100215	0.001063	0.107634	0.007274
8	1167.302	91.80985	0.045440	4.429900	2.648326	0.542083	0.308740	0.099389	0.001520	0.106843	0.007909
9	1170.471	91.31843	0.045228	4.844195	2.730159	0.539493	0.307119	0.099004	0.001691	0.106265	0.008420
10	1191.253	88.16168	0.043771	6.812233	3.955724	0.521381	0.296570	0.095698	0.001665	0.102825	0.008459

The self-shock of Nitrous oxide slightly declines from 99% to 95% for recent years. In case of railway transport there is positive increasing trend emerging from 0.009% to 0.039% for passenger carried and 0.060% to 2.75% in case of railway goods transported. Rest of the explanatory variables shows increasing shock dispersion from 0.008% to 0.06% in GDP, 0.125% to 0.822% in FDI, 0.036% to 0.145% in trade openness, and 0.0013% to 0.014% in population growth from the quarter 1 to quarter 10th. While energy demand in first quarter shows 0.072% shock and then 0.051% for 7th and 8th quarter showing increasing trend to 10th quarter for 0.04% shock. Finally, In the case of methane emission the self-shock or own shock has declined from 99% to 88%. The quarter 3rd shows variation in the shocks of independent variables such as 0.045% in GDP, 1.43% in RPC, 0.441% in RGT, 0.095% in FDI, 0.106% in energy demand. Trade openness shows a minor shock trend throughout the years moving from 0.0003% to 0.0016%. Population growth and trade responds less to methane emissions for the upcoming next 10 years. The demonstrated table as above shows the variance decomposition analysis for the coming ten years.

Pairwise DumitrescuHurlin Panel Causality Tests

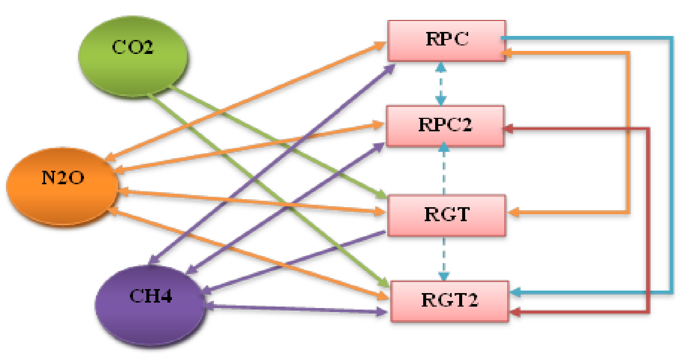

Figure 3: Granger Causation is Unidirectional for CO2, and bi-directional for both N2O and CH4

The granger causation shows a bidirectional association of railway transport and its square term to N2O and CH4. While there is unidirectional causation running from carbon emissions to railway goods transport and square term. Moreover, railway passenger shows bidirectional causation to railway cargo and unidirectional association is running from railway passenger to railway cargo. This causation is sketched only in context to railway transportation to pollution emissions rest whole statistical causation table is given in the appendix.

Diagnostic Test

The Null hypotheses of Serial Correlation LM and Heteroskedasticity are accepted for insignificant values. The probability statistics of LM test for the CO2 model is 0.543, NO2 has 0.438 and methane has 0.538. This shows the absence of serial correlation in the considered models. The Heteroskedascity test shows the insignificant probability value for the CO2 model is 0.827, NO2 has 0.711 and methane has 0.271 that accepts the null hypothesis i-e there is no heteroscdasticity.

Table 10: Results of Serial Correlation LM and ARCH tests

Diagnostic Tests	Dependent Variable	CO2	N2O	CH4
Breusch-Godfrey Serial Correlation LM Test	F-statistic	0.611	0. 444	0. 111
	Obs*R-squared	1.251	1. 607	1.556
	Prob. F(stats)	0.543	0. 430	0.532
	Prob. Chi-Square	0.533	0. 438	0.538
Heteroskedasticity Test: ARCH	F-statistic	0.477	0. 730	0.870
	Obs*R-squared	0.478	0.785	0. 850
	Prob. F(stats)	0.827	0.711	0. 271
	Prob. Chi-Square	0.826	0.681	0. 268

- **CUSUM Stability Test:**

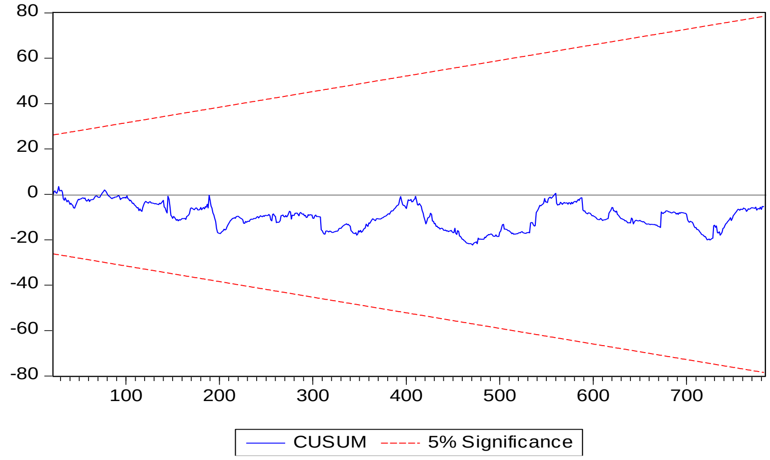

Figure 4: Dependent Variable: CO2 Emissions

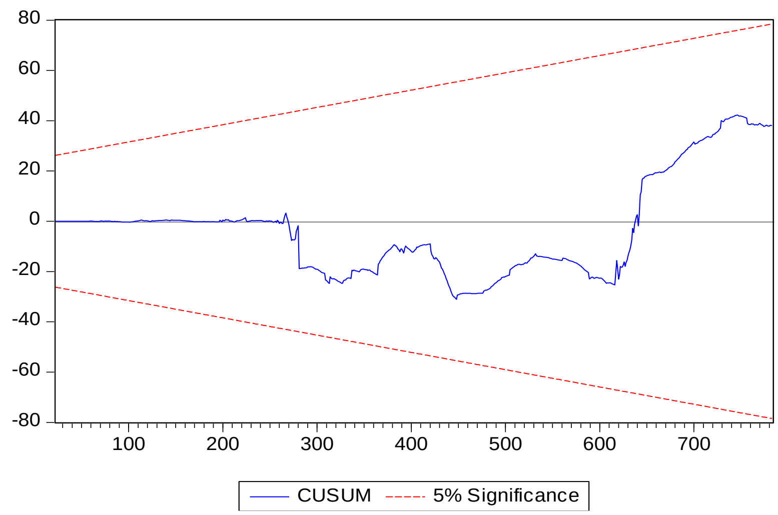

Figure 5: Dependent Variable: N2O Emissions

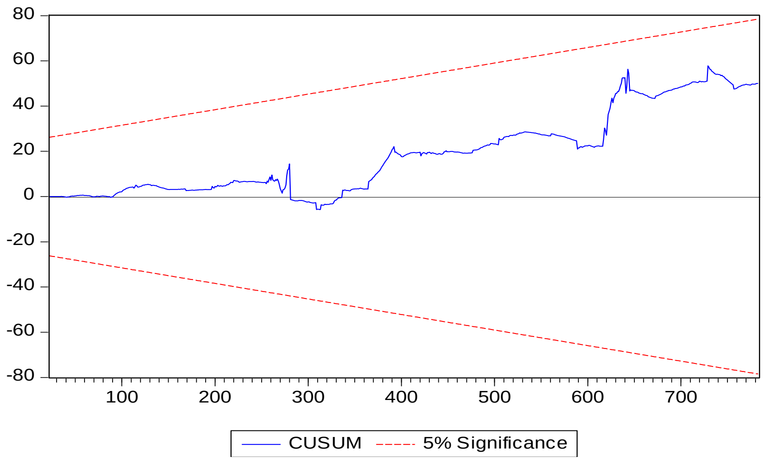

Figure 6: Dependent Variable: CH4 Emissions

The CUSUM shows that collective sum of randomness. The above plots show the stability of the model that is the plotted lines exist in the critical region signifying the stability of the all the three models.

Conclusion and Recommendations:

The central element and the real challenge to the global world is the climate change. Transportation system contributes a significant share and develops many environmental challenges. The current analysis validates the existence of "inverted U shape" relationship in case of only nitrous oxide emissions for railway transport. On the contrary, the other two detrimental emissions carbon and methane exhibit "U shape" railway Kuznet curve. As a whole developed nations have almost achieved a certain level in lowering pollution emission but still "U" shape in case of CO_2 and CH_4 requires the strategic control policies.

The econometric results depict the phenomenon of environmental degradation even in the highly developed nations. Moreover, GDP and trade openness increases the pollution emissions in all the cases. It exhibits that without introducing technological advancement, premeditated environmental policies and eco-environment fuel utilization, the high income nations can not achieve the basic environmental standards.

In addition, the developed nations have contributed positively to environment in context of FDI, energy demand and population in respect of carbon emissions. On the other hand, trade openness and economic growth needs to be controlled at sustainable level by considering environmental problems.

For Nitrous Oxide emissions only trade openness and population density increases the pollution, although they have achieved a downward turning point of 0.2580 by protecting environment. Finally, methane emission increases due to increase in GDP, trade openness and population growth. Therefore, environmental policies, emissions standards and conservation still lag behind the optimal level in case of high income transitions.

This analysis suggests that railway sector should be modified to zero carbon emission by adopting electric engines based on exploiting renewable energy resources, eco-driving and crucial operational measures. Fuel-saving traveler and freight equipment, hybrid switch engines and hydrogen-powered fuel cell trains can radically cut the diesel fuel as well as the emissions of carbon, methane and nitrogen oxide (Gurz et al., 2017)

Summing up, railway system can become sustainable mode if fuel efficient resources are employed, modernization and upgradation in sector are made along with adopting eco-friendly and renewablenatural resources.

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Appendix:

List of High Income nations:

1. Australia
2. Austria
3. Belgium
4. Canada
5. Chile
6. Czech Republic
7. Denmark
8. Estonia
9. Finland
10. France
11. Germany
12. Greece
13. Hungary
14. Ireland
15. Israel
16. Italy
17. Japan
18. Korea, Rep.
19. Latvia
20. Lithuania
21. Luxembourg
22. Netherlands
23. New Zealand
24. Norway
25. Poland
26. Portugal
27. Saudi Arabia
28. Singapore
29. Slovak Republic
30. Slovenia
31. Spain
32. Sweden
33. Switzerland
34. United Arab Emirates
35. United Kingdom
36. United States
37. Uruguay

Pairwise DumitrescuHurlin Panel Causality Tests

Pairwise DumitrescuHurlin Panel Causality Tests Date: 09/15/18 Time: 18:07 Sample: 1990 2017 Lags: 1			
Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
GDP does not homogeneously cause CO2	3.99863	10.6906	0.0000
CO2 does not homogeneously cause GDP	1.96369	3.20888	0.0013
RPC does not homogeneously cause CO2	2.67257	5.81516	6.E-09
CO2 does not homogeneously cause RPC	3.23613	7.88715	3.E-15
RPC2 does not homogeneously cause CO2	2.78984	6.24630	4.E-10
CO2 does not homogeneously cause RPC2	3.23192	7.87169	4.E-15
RGT does not homogeneously cause CO2	2.55527	5.38388	7.E-08
CO2 does not homogeneously cause RGT	3.39049	8.45467	0.0000
RGT2 does not homogeneously cause CO2	2.48792	5.13628	3.E-07
CO2 does not homogeneously cause RGT2	3.76976	9.84910	0.0000
FDI does not homogeneously cause CO2	1.43661	1.27101	0.2037
CO2 does not homogeneously cause FDI	3.07865	7.30816	3.E-13
TOP does not homogeneously cause CO2	3.00010	7.01935	2.E-12
CO2 does not homogeneously cause TOP	1.68103	2.16964	0.0300
ED does not homogeneously cause CO2	2.06541	3.58286	0.0003
CO2 does not homogeneously cause ED	2.29360	4.42185	1.E-05
PG does not homogeneously cause CO2	4.58775	12.8566	0.0000
CO2 does not homogeneously cause PG	5.90216	17.6891	0.0000
RPC does not homogeneously cause GDP	2.36102	4.66972	3.E-06
GDP does not homogeneously cause RPC	5.10538	14.7597	0.0000
RPC2 does not homogeneously cause GDP	2.14014	3.85763	0.0001
GDP does not homogeneously cause RPC2	5.68408	16.8873	0.0000
RGT does not homogeneously cause GDP	1.87051	2.86628	0.0042
GDP does not homogeneously cause RGT	4.08641	11.0133	0.0000
RGT2 does not homogeneously cause GDP	1.95359	3.17175	0.0015
GDP does not homogeneously cause RGT2	4.76533	13.5094	0.0000
FDI does not homogeneously cause GDP	1.43652	1.27066	0.2038
GDP does not homogeneously cause FDI	3.84569	10.1283	0.0000
TOP does not homogeneously cause GDP	2.32239	4.52769	6.E-06
GDP does not homogeneously cause TOP	2.61701	5.61087	2.E-08
ED does not homogeneously cause GDP	1.77284	2.50718	0.0122
GDP does not homogeneously cause ED	3.62420	9.31393	0.0000
PG does not homogeneously cause GDP	1.48901	1.46367	0.1433
GDP does not homogeneously cause PG	12.3056	41.2321	0.0000
RPC2 does not homogeneously cause RPC	4.69992	13.2689	0.0000
RPC does not homogeneously cause RPC2	9.48670	30.8681	0.0000
RGT does not homogeneously cause RPC	19.8916	69.1228	0.0000
RPC does not homogeneously cause RGT	4.39268	12.1394	0.0000
RGT2 does not homogeneously cause RPC	2.86551	6.52454	7.E-11
RPC does not homogeneously cause RGT2	5.82961	17.4224	0.0000
RPC does not homogeneously cause FDI	3.01574	7.07688	1.E-12
TOP does not homogeneously cause RPC	3.89804	10.3208	0.0000
RPC does not homogeneously cause TOP	1.69845	2.23371	0.0255
ED does not homogeneously cause RPC	4.50817	12.5640	0.0000
RPC does not homogeneously cause ED	2.90802	6.68082	2.E-11
PG does not homogeneously cause RPC	2.71334	5.96507	2.E-09

RPC does not homogeneously cause PG	4.45355	12.3631	0.0000
RGT does not homogeneously cause RPC2	4.10986	11.0995	0.0000
RPC2 does not homogeneously cause RGT	2.77429	6.18916	6.E-10
RGT2 does not homogeneously cause RPC2	22.3372	78.1145	0.0000
RPC2 does not homogeneously cause RGT2	6.16927	18.6712	0.0000
FDI does not homogeneously cause RPC2	1.43469	1.26393	0.2063
RPC2 does not homogeneously cause FDI	2.97887	6.94133	4.E-12
TOP does not homogeneously cause RPC2	4.30527	11.8180	0.0000
RPC2 does not homogeneously cause TOP	1.67370	2.14269	0.0321
ED does not homogeneously cause RPC2	4.89400	13.9825	0.0000
RPC2 does not homogeneously cause ED	2.59760	5.53951	3.E-08
PG does not homogeneously cause RPC2	4.14220	11.2184	0.0000
RPC2 does not homogeneously cause PG	4.69939	13.2670	0.0000
RGT2 does not homogeneously cause RGT	2.19784	4.06977	5.E-05
RGT does not homogeneously cause RGT2	10.5163	34.6536	0.0000
FDI does not homogeneously cause RGT	1.85965	2.82636	0.0047
RGT does not homogeneously cause FDI	3.07249	7.28553	3.E-13
TOP does not homogeneously cause RGT	3.42840	8.59405	0.0000
RGT does not homogeneously cause TOP	2.24698	4.25041	2.E-05
ED does not homogeneously cause RGT	3.13143	7.50220	6.E-14
RGT does not homogeneously cause ED	3.59704	9.21407	0.0000
PG does not homogeneously cause RGT	4.46766	12.4150	0.0000
RGT does not homogeneously cause PG	7.38889	23.1553	0.0000
FDI does not homogeneously cause RGT2	1.91548	3.03164	0.0024
RGT2 does not homogeneously cause FDI	3.26272	7.98490	1.E-15
TOP does not homogeneously cause RGT2	4.01677	10.7573	0.0000
RGT2 does not homogeneously cause TOP	1.93127	3.08968	0.0020
ED does not homogeneously cause RGT2	3.25412	7.95329	2.E-15
RGT2 does not homogeneously cause ED	3.66275	9.45566	0.0000
PG does not homogeneously cause RGT2	5.40504	15.8614	0.0000
RGT2 does not homogeneously cause PG	6.93365	21.4815	0.0000
TOP does not homogeneously cause FDI	2.31625	4.50511	7.E-06
FDI does not homogeneously cause TOP	1.88167	2.90733	0.0036
ED does not homogeneously cause FDI	2.04039	3.49087	0.0005
FDI does not homogeneously cause ED	1.85239	2.79967	0.0051
PG does not homogeneously cause FDI	3.53212	8.97540	0.0000
FDI does not homogeneously cause PG	3.41339	8.53887	0.0000
ED does not homogeneously cause TOP	1.35603	0.97477	0.3297
TOP does not homogeneously cause ED	3.14953	7.56875	4.E-14
PG does not homogeneously cause TOP	2.17584	3.98888	7.E-05
TOP does not homogeneously cause PG	5.14861	14.9186	0.0000
PG does not homogeneously cause ED	4.75704	13.4790	0.0000
ED does not homogeneously cause PG	15.6534	53.5409	0.0000

Pairwise DumitrescuHurlin Panel Causality Tests
Date: 15/09/18 Time: 22:25
Sample: 1990 2017
Lags: 1

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
GDP does not homogeneously cause N2O	8.97593	28.9902	0.0000
N2O does not homogeneously cause GDP	1.56002	1.72475	0.0846
RPC does not homogeneously cause N2O	4.67244	13.1679	0.0000
N2O does not homogeneously cause RPC	4.05423	10.8950	0.0000
RPC2 does not homogeneously cause N2O	4.44726	12.3400	0.0000

N2O does not homogeneously cause RPC2	5.42184	15.9232	0.0000
RGT does not homogeneously cause N2O	6.27732	19.0684	0.0000
N2O does not homogeneously cause RGT	4.09068	11.0290	0.0000
RGT2 does not homogeneously cause N2O	6.04937	18.2304	0.0000
N2O does not homogeneously cause RGT2	6.07791	18.3353	0.0000
FDI does not homogeneously cause N2O	2.20120	4.08210	4.E-05
N2O does not homogeneously cause FDI	2.04552	3.50974	0.0004
TOP does not homogeneously cause N2O	5.67708	16.8616	0.0000
N2O does not homogeneously cause TOP	1.63733	2.00900	0.0445
ED does not homogeneously cause N2O	4.37938	12.0904	0.0000
N2O does not homogeneously cause ED	2.19766	4.06908	5.E-05
PG does not homogeneously cause N2O	8.57879	27.5301	0.0000
N2O does not homogeneously cause PG	15.6378	53.4835	0.0000
RPC does not homogeneously cause GDP	2.36102	4.66972	3.E-06
GDP does not homogeneously cause RPC	5.10538	14.7597	0.0000
RPC2 does not homogeneously cause GDP	2.14014	3.85763	0.0001
GDP does not homogeneously cause RPC2	5.68408	16.8873	0.0000
RGT does not homogeneously cause GDP	1.87051	2.86628	0.0042
GDP does not homogeneously cause RGT	4.08641	11.0133	0.0000
RGT2 does not homogeneously cause GDP	1.95359	3.17175	0.0015
GDP does not homogeneously cause RGT2	4.76533	13.5094	0.0000
FDI does not homogeneously cause GDP	1.43652	1.27066	0.2038
GDP does not homogeneously cause FDI	3.84569	10.1283	0.0000
TOP does not homogeneously cause GDP	2.32239	4.52769	6.E-06
GDP does not homogeneously cause TOP	2.61701	5.61087	2.E-08
ED does not homogeneously cause GDP	1.77284	2.50718	0.0122
GDP does not homogeneously cause ED	3.62420	9.31393	0.0000
PG does not homogeneously cause GDP	1.48901	1.46367	0.1433
GDP does not homogeneously cause PG	12.3056	41.2321	0.0000
RPC2 does not homogeneously cause RPC	4.69992	13.2689	0.0000
RPC does not homogeneously cause RPC2	9.48670	30.8681	0.0000
RGT does not homogeneously cause RPC	19.8916	69.1228	0.0000
RPC does not homogeneously cause RGT	4.39268	12.1394	0.0000
RGT2 does not homogeneously cause RPC	2.86551	6.52454	7.E-11
RPC does not homogeneously cause RGT2	5.82961	17.4224	0.0000
FDI does not homogeneously cause RPC	1.28071	0.69782	0.4853
RPC does not homogeneously cause FDI	3.01574	7.07688	1.E-12
TOP does not homogeneously cause RPC	3.89804	10.3208	0.0000
RPC does not homogeneously cause TOP	1.69845	2.23371	0.0255
ED does not homogeneously cause RPC	4.50817	12.5640	0.0000
RPC does not homogeneously cause ED	2.90802	6.68082	2.E-11
PG does not homogeneously cause RPC	2.71334	5.96507	2.E-09
RPC does not homogeneously cause PG	4.45355	12.3631	0.0000
RGT does not homogeneously cause RPC2	4.10986	11.0995	0.0000
RPC2 does not homogeneously cause RGT	2.77429	6.18916	6.E-10
RGT2 does not homogeneously cause RPC2	22.3372	78.1145	0.0000
RPC2 does not homogeneously cause RGT2	6.16927	18.6712	0.0000
FDI does not homogeneously cause RPC2	1.43469	1.26393	0.2063
RPC2 does not homogeneously cause FDI	2.97887	6.94133	4.E-12
TOP does not homogeneously cause RPC2	4.30527	11.8180	0.0000
RPC2 does not homogeneously cause TOP	1.67370	2.14269	0.0321
ED does not homogeneously cause RPC2	4.89400	13.9825	0.0000
RPC2 does not homogeneously cause ED	2.59760	5.53951	3.E-08

PG does not homogeneously cause RPC2	4.14220	11.2184	0.0000
RPC2 does not homogeneously cause PG	4.69939	13.2670	0.0000
RGT2 does not homogeneously cause RGT	2.19784	4.06977	5.E-05
RGT does not homogeneously cause RGT2	10.5163	34.6536	0.0000
FDI does not homogeneously cause RGT	1.85965	2.82636	0.0047
RGT does not homogeneously cause FDI	3.07249	7.28553	3.E-13
TOP does not homogeneously cause RGT	3.42840	8.59405	0.0000
RGT does not homogeneously cause TOP	2.24698	4.25041	2.E-05
ED does not homogeneously cause RGT	3.13143	7.50220	6.E-14
RGT does not homogeneously cause ED	3.59704	9.21407	0.0000
PG does not homogeneously cause RGT	4.46766	12.4150	0.0000
RGT does not homogeneously cause PG	7.38889	23.1553	0.0000
FDI does not homogeneously cause RGT2	1.91548	3.03164	0.0024
RGT2 does not homogeneously cause FDI	3.26272	7.98490	1.E-15
TOP does not homogeneously cause RGT2	4.01677	10.7573	0.0000
RGT2 does not homogeneously cause TOP	1.93127	3.08968	0.0020
ED does not homogeneously cause RGT2	3.25412	7.95329	2.E-15
RGT2 does not homogeneously cause ED	3.66275	9.45566	0.0000
PG does not homogeneously cause RGT2	5.40504	15.8614	0.0000
RGT2 does not homogeneously cause PG	6.93365	21.4815	0.0000
TOP does not homogeneously cause FDI	2.31625	4.50511	7.E-06
FDI does not homogeneously cause TOP	1.88167	2.90733	0.0036
ED does not homogeneously cause FDI	2.04039	3.49087	0.0005
FDI does not homogeneously cause ED	1.85239	2.79967	0.0051
PG does not homogeneously cause FDI	3.53212	8.97540	0.0000
FDI does not homogeneously cause PG	3.41339	8.53887	0.0000
ED does not homogeneously cause TOP	1.35603	0.97477	0.3297
TOP does not homogeneously cause ED	3.14953	7.56875	4.E-14
PG does not homogeneously cause TOP	2.17584	3.98888	7.E-05
TOP does not homogeneously cause PG	5.14861	14.9186	0.0000
PG does not homogeneously cause ED	4.75704	13.4790	0.0000
ED does not homogeneously cause PG	15.6534	53.5409	0.0000

Pairwise DumitrescuHurlin Panel Causality Tests
Date: 09/15/18 Time: 18:42
Sample: 1990 2017
Lags: 1

Null Hypothesis:	W-Stat.	Zbar-Stat.	Prob.
GDP does not homogeneously cause CH4	10.2549	33.6925	0.0000
CH4 does not homogeneously cause GDP	2.52628	5.27731	1.E-07
RPC does not homogeneously cause CH4	5.12542	14.8333	0.0000
CH4 does not homogeneously cause RPC	4.15954	11.2822	0.0000
RPC2 does not homogeneously cause CH4	4.66184	13.1289	0.0000
CH4 does not homogeneously cause RPC2	6.65483	20.4564	0.0000
RGT does not homogeneously cause CH4	5.90509	17.6999	0.0000
CH4 does not homogeneously cause RGT	2.18874	4.03631	5.E-05
RGT2 does not homogeneously cause CH4	5.46551	16.0837	0.0000
CH4 does not homogeneously cause RGT2	7.08057	22.0217	0.0000
FDI does not homogeneously cause CH4	1.92264	3.05796	0.0022
CH4 does not homogeneously cause FDI	3.17518	7.66308	2.E-14
TOP does not homogeneously cause CH4	4.82996	13.7470	0.0000
CH4 does not homogeneously cause TOP	2.60616	5.57099	3.E-08
ED does not homogeneously cause CH4	6.27848	19.0727	0.0000
CH4 does not homogeneously cause ED	3.15296	7.58136	3.E-14

PG does not homogeneously cause CH4	11.0734	36.7019	0.0000
CH4 does not homogeneously cause PG	9.90928	32.4218	0.0000
RPC does not homogeneously cause GDP	2.36102	4.66972	3.E-06
GDP does not homogeneously cause RPC	5.10538	14.7597	0.0000
RPC2 does not homogeneously cause GDP	2.14014	3.85763	0.0001
GDP does not homogeneously cause RPC2	5.68408	16.8873	0.0000
RGT does not homogeneously cause GDP	1.87051	2.86628	0.0042
GDP does not homogeneously cause RGT	4.08641	11.0133	0.0000
RGT2 does not homogeneously cause GDP	1.95359	3.17175	0.0015
GDP does not homogeneously cause RGT2	4.76533	13.5094	0.0000
FDI does not homogeneously cause GDP	1.43652	1.27066	0.2038
GDP does not homogeneously cause FDI	3.84569	10.1283	0.0000
TOP does not homogeneously cause GDP	2.32239	4.52769	6.E-06
GDP does not homogeneously cause TOP	2.61701	5.61087	2.E-08
ED does not homogeneously cause GDP	1.77284	2.50718	0.0122
GDP does not homogeneously cause ED	3.62420	9.31393	0.0000
PG does not homogeneously cause GDP	1.48901	1.46367	0.1433
GDP does not homogeneously cause PG	12.3056	41.2321	0.0000
RPC2 does not homogeneously cause RPC	4.69992	13.2689	0.0000
RPC does not homogeneously cause RPC2	9.48670	30.8681	0.0000
RGT does not homogeneously cause RPC	19.8916	69.1228	0.0000
RPC does not homogeneously cause RGT	4.39268	12.1394	0.0000
RGT2 does not homogeneously cause RPC	2.86551	6.52454	7.E-11
RPC does not homogeneously cause RGT2	5.82961	17.4224	0.0000
FDI does not homogeneously cause RPC	1.28071	0.69782	0.4853
RPC does not homogeneously cause FDI	3.01574	7.07688	1.E-12
TOP does not homogeneously cause RPC	3.89804	10.3208	0.0000
RPC does not homogeneously cause TOP	1.69845	2.23371	0.0255
ED does not homogeneously cause RPC	4.50817	12.5640	0.0000
RPC does not homogeneously cause ED	2.90802	6.68082	2.E-11
PG does not homogeneously cause RPC	2.71334	5.96507	2.E-09
RPC does not homogeneously cause PG	4.45355	12.3631	0.0000
RGT does not homogeneously cause RPC2	4.10986	11.0995	0.0000
RPC2 does not homogeneously cause RGT	2.77429	6.18916	6.E-10
RGT2 does not homogeneously cause RPC2	22.3372	78.1145	0.0000
RPC2 does not homogeneously cause RGT2	6.16927	18.6712	0.0000
FDI does not homogeneously cause RPC2	1.43469	1.26393	0.2063
RPC2 does not homogeneously cause FDI	2.97887	6.94133	4.E-12
TOP does not homogeneously cause RPC2	4.30527	11.8180	0.0000
RPC2 does not homogeneously cause TOP	1.67370	2.14269	0.0321
ED does not homogeneously cause RPC2	4.89400	13.9825	0.0000
RPC2 does not homogeneously cause ED	2.59760	5.53951	3.E-08
PG does not homogeneously cause RPC2	4.14220	11.2184	0.0000
RPC2 does not homogeneously cause PG	4.69939	13.2670	0.0000
RGT2 does not homogeneously cause RGT	2.19784	4.06977	5.E-05
RGT does not homogeneously cause RGT2	10.5163	34.6536	0.0000
FDI does not homogeneously cause RGT	1.85965	2.82636	0.0047
RGT does not homogeneously cause FDI	3.07249	7.28553	3.E-13
TOP does not homogeneously cause RGT	3.42840	8.59405	0.0000
RGT does not homogeneously cause TOP	2.24698	4.25041	2.E-05
ED does not homogeneously cause RGT	3.13143	7.50220	6.E-14
RGT does not homogeneously cause ED	3.59704	9.21407	0.0000
PG does not homogeneously cause RGT	4.46766	12.4150	0.0000

RGT does not homogeneously cause PG	7.38889	23.1553	0.0000
FDI does not homogeneously cause RGT2	1.91548	3.03164	0.0024
RGT2 does not homogeneously cause FDI	3.26272	7.98490	1.E-15
TOP does not homogeneously cause RGT2	4.01677	10.7573	0.0000
RGT2 does not homogeneously cause TOP	1.93127	3.08968	0.0020
ED does not homogeneously cause RGT2	3.25412	7.95329	2.E-15
RGT2 does not homogeneously cause ED	3.66275	9.45566	0.0000
PG does not homogeneously cause RGT2	5.40504	15.8614	0.0000
RGT2 does not homogeneously cause PG	6.93365	21.4815	0.0000
TOP does not homogeneously cause FDI	2.31625	4.50511	7.E-06
FDI does not homogeneously cause TOP	1.88167	2.90733	0.0036
ED does not homogeneously cause FDI	2.04039	3.49087	0.0005
FDI does not homogeneously cause ED	1.85239	2.79967	0.0051
PG does not homogeneously cause FDI	3.53212	8.97540	0.0000
FDI does not homogeneously cause PG	3.41339	8.53887	0.0000
ED does not homogeneously cause TOP	1.35603	0.97477	0.3297
TOP does not homogeneously cause ED	3.14953	7.56875	4.E-14
PG does not homogeneously cause TOP	2.17584	3.98888	7.E-05
TOP does not homogeneously cause PG	5.14861	14.9186	0.0000
PG does not homogeneously cause ED	4.75704	13.4790	0.0000
ED does not homogeneously cause PG	15.6534	53.5409	0.0000