



# Balancing Growth and Sustainability: Evidence from GDP, Population, and CO<sub>2</sub> Emissions from Transport in BRICS Countries

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**Abstract.** The present study makes an attempt to understand how CO<sub>2</sub> Emissions from Transport, could be linked to GDP and Population for five BRICS nations (Brazil, Russia, India, China and S. Africa) by analyzing data for the period 1990-2023. The aim is to assess whether such linkages exist and, if they do, to evaluate the extent to which economic growth and population contribute to emissions both for each BRICS country individually and for the group as a whole. Further, to enhance the robustness of the analysis, time series, pooled and panel (fixed and random effects) regression techniques have been employed to examine the impact of GDP and population on transport emissions. The comparison of various models revealed that the appropriate model as applicable on our data was Fixed Effects. The results of the study pointed out that economic growth was a major driver of transport emissions across all BRICS nations; both individually and collectively whereas population did not exhibit a similar impact. It was also observed that in pursuit of economic growth, many BRICS nations had made substantial investments in infrastructure and large-scale development projects. The study therefore recommends BRICS nations to make all infrastructure investments sustainable to support emission reduction due to transport. The study also recommends promoting low carbon transport technologies including switching to green and hybrid fuels, building infrastructure using sustainable technologies and emphasizing circular economy, all must be prioritized and strongly implemented keeping into consideration their role in emissions reduction.

**Keywords:** Transport Emissions, BRICS, Fixed Effects, Random Effects, Variance Inflation Factor.

## 1 Introduction

The study makes an attempt to analyse the relation between, GDP, Population and CO<sub>2</sub> Emissions from Transport for five BRICS nations (Brazil, Russia, India, China and S. Africa) for the period 1990-2023. The sources of data include world development indicators (<https://databank.worldbank.org>). The aim is to ascertain the extent to which growth and population are responsible and have contributed to these emissions in each

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of the BRICS nations. The issue is particularly significant in the context of BRICS, as studies including [1], [2] amongst others indicated that the relationship between economic growth, population dynamics, and transport emissions was stronger and more positive amongst BRICS nations as compared to what was observed in developed countries. Then another study by Shahani and Badaik, (2024) showed a strong co-integrating relation between ecological footprint, GDP, biocapacity and Trade in four BRICS.

The BRICS, as a group became popular due to their growth stories which was largely due to some common features enjoyed by these countries including population and labour power, rapid urbanization, growing middle class with government taking active role in country's development. On the other hand, each of the BRICS nations has followed a distinct economic trajectory shaped by its unique resource base and structural strengths. Brazil has leveraged its vast agricultural and mineral wealth; Russia's growth has centered on its dominance in oil, gas and other strategic natural resources; India's expansion has been propelled by a strong agrarian base along with skilled human capital and a globally competitive IT sector; China has emerged as the world's leading manufacturing hub backed by large-scale industrialization; and South Africa has positioned itself as a gateway to African markets, supported by its abundance of precious metals such as gold and platinum. [3]

On the other hand, concerns have been raised regarding the sustainability of this growth. Evidence indicates that economic expansion in many BRICS countries has been closely linked with rising greenhouse gas (GHG) emissions. Investigating this nexus constitutes the central objective of the present study.

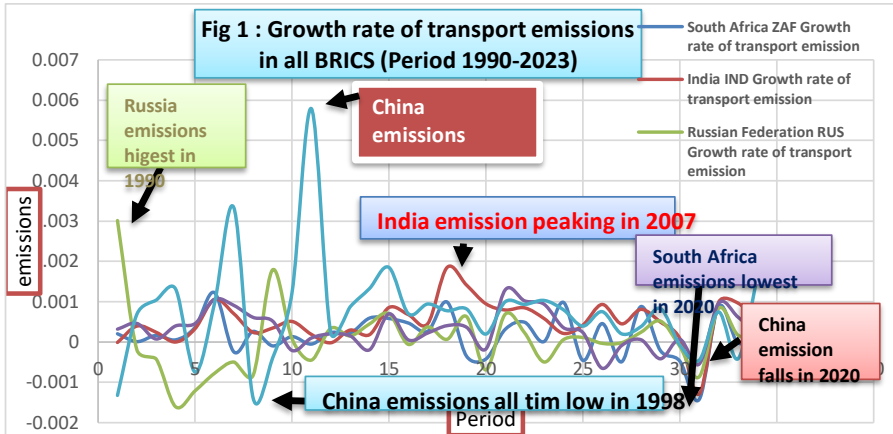
Hence, in view of these concerns, the present study empirically examines the relationship between economic growth and demographic pressure on environmental quality. Specifically, it investigates the impact of GDP and population on transport-related CO<sub>2</sub> emissions in each of the five BRICS nations. Table 1 provides summary information on the variables along with their unit of measurement.

**Table 1.** Summary Information of the Variables included and their sources of data

Sr No.	Name of the Indicator/ Notation used	Unit of Measurement	Source of Data
1	Carbon dioxide emissions from Transport (TE)	(Mt CO <sub>2</sub> e, The measure is standardized to carbon dioxide equivalent values using the Global Warming Potential (GWP) factors)	World Development Indicators
2.	GDP	GDP per capita (constant 2015 US\$)	World Development Indicators
3.	Pop	Population growth (annual %)	World Development Indicators

*Source: Author's Own compilation*

The study also presents an analysis of growth rate of transport emissions for each of the BRICS nations over the period (1990-2023), details of the same are presented graphically ( Fig 1). The figure provides a graphic representation of annualized growth in transport emissions in all the five BRICS, with peaks and declines for these emissions been depicted separately in the figure.



**Fig.1.** Growth rate of transportation emissions in all BRICS (1990 - 2023)

Figure 1 reveals that China's emissions from transport peaked at the end of 2000, the rise from 1999 to 2000 was extremely sharp and the year 2000 coincided with exceptionally high economic growth of GDP witnessed by China which averaged around 10 % during this period. The growth in industrial output too was exceptional during this period and with urban expansion growing , this resulted in quantum rise in household incomes, which resulted in raising demand for vehicles and this together with poor emission standards gave an indication that things were slowly beginning to move out of control. However, post 2000, the country did enforce stringent vehicle emission standards, also took steps to promote public transport, and launched massive EV programs which over a period of time helped the country to achieve control over emissions.

Coming to another BRICS country, India, the year 2006 could be considered as turning point with emissions peaking in 2007 and then declining at a gradual pace. The country initiated some major steps around 2007-08 including public transport boost, metro in major cities and introduced the EV push. The country however saw its second major spike in emissions growth in 2021 which could be due to large scale private vehicles hitting the roads mainly due to rising incomes due to visible positive effect of growth on the economy. Thus opening up of the economy after Covid-19 pandemic was also partially responsible for this spike in emissions. Furthermore, inspite of many measures

taken by the government in order to improve quality of emissions, the result could not be seen on the ground and questions were raised about implementation of environment norms.

As far as Russia is concerned, initially the emissions were high in 1990s due to country's low priority to the environment sector primarily because of country's major challenge due to transition from USSR collapse. However, this was brought within control after the country launched major energy efficiency initiatives from 2000 onwards (fuel standards, metro, modernize vehicle fleet amongst others)

Then, South Africa was another country which too faced problems with respect to emissions in 1990s as the country's focus was solely on growth, however in terms of severity, this was not the same as compared to other BRICS. The country also later initiated environment friendly measures (cleaner fuels, focus on public transport, railway electrification) and achieved the lowest levels of emissions in 2020, which could partially be attributed to measures implemented and initiatives taken in this direction and partially due to impact of Covid-19 on emissions.

Finally, we have Brazil, the country which could be considered as the earliest of BRICS to take steps in the direction of environment protection, thanks to its ethanol and biofuel policy which was launched as early as in 1970 but gained momentum in 1990s. Thus, during the period of 1990s when other BRICS were struggling with emissions, Brazil could manage controlled emissions resulting in very few periods of spikes.

Moving forward, to achieve the stated objectives, the study has developed its empirical analytical framework using both time-series and panel regression techniques. The study would be developing a formal econometric test of how emissions from transport are being impacted by two variables; GDP and Population.

All the variables under the study are converted to their growth rates by applying the formula:  $\frac{\Delta x_t - \Delta x_{t-1}}{\Delta x_{t-1}}$ . This has been done primarily because growth rates as against raw prices are more stationary, free from trends and wild fluctuations. Furthermore, need for panel data analysis was felt due to use of annual data which could provide limited number of observations and degrees of freedom. It was also felt that the analysis under panel data be combined with time series analysis as this could also explain within country variations in dependent variable, the same being ignored under Panel.

The remainder of this paper is structured as follows. Section 2 provides the review of existing studies on this aspect. Section 3 details the research methodology, models employed along with equations used for empirical testing. Section 4 discusses the empirical results, accompanied by the corresponding tables and their interpretations. Section 5 concludes the study by summarizing the key findings, and providing policy implications. The paper ends with a list of references.

## 2 Review of Literature

Under literature review section we would first be discussing existing studies on environment which have included BRICS as their sample followed by some studies which have included transport emissions, which is target variable for the present study as one their variables.

[4] in their study examined how usage of energy and technology improvements resulted in environmental deterioration in BRICS. The study included a large number of environment proxy variables and found a positive relation between these environment variables and technology improvements. This comes as a surprise as many researchers viewed technology improvement to be negatively related to environment degradation. The study therefore recommended that BRICS nations should consider climate uncertainty policies in their policy making. These policies are rather flexible and are so designed to enable the policy to evolve as new information arrives. On the other hand, [5] in their study tried to assess the contribution of two important segments of transport viz. freight and passenger to air pollution levels in BRICS. The study used a new proxy variable of air pollution; PM 2.5 and found that the impact of freight transport on this variable was almost double than that of passenger transport. With respect to other results, it was seen that the economic growth in BRICS was positively linked to air pollution and EKC Model when applied to BRICS using this environment proxy was validated.

Then, in another study, [6] also showed EKC validity for BRICS nations. They found evidence that energy consumption was positively linked to emissions throughout the study period while GDP which was initially associated with rise in emissions, eventually landed up with an inverse relation. The study also brought forward an interesting conclusion with respect to an uncommon variable, FDI outflow. The study results confirmed that outward FDI improved environment quality in BRICS nations. Again, [7] too tested for EKC with their model being applied on emissions due to road transport. The sample included six countries, five of these belonging to BRICS. Their results although showed evidence for validity of EKC but found that the turning point was higher than current GDP, an indication of shifting of the decline phase more into future as compared to traditional GDP. Furthermore, amongst all BRICS, the most promising country was Russia and after removing this country from the sample, they could notice non validity of EKC on road transport emissions.

Next moving to some of the studies which are non BRICS sample studies but have focused on transport sector and how the sector has contributed to rise in emissions and these include a study by [8] where they focused on transport carbon intensity which is a measure of how much carbon (CO<sub>2</sub>) is emitted per unit of transport activity and their study results showed that this variable(carbon intensity from transport) was positively and significantly associated with expenditure on healthcare and money spend by household sector on transport. Moreover, in terms of relation amongst these variables, the results showed a bi-directional relation amongst all the three variables.

Then an interesting study was carried out by [9] to understand impact of innovations (patents, trademarks) on CO<sub>2</sub> emissions by transport sector. Although many researchers would expect the relation to be negative with emissions as innovations are viewed as more of EVs and other environment friendly alternatives, results however proved the opposite i.e. revealed a positive relation between innovations and CO<sub>2</sub> emissions both in developing and developed countries, with the relation being stronger in developed countries. The findings thus proved that innovations cannot be considered blindly as means which could reduce transport CO<sub>2</sub> emissions as innovations under transport domain also includes addition of more and more sophisticated vehicles, adding more capacity by design modification of existing vehicles, taking steps to increasing transport mobility amongst others and it would not be incorrect to say that some of these innovations contribute to higher emissions especially when innovation has not been carried out with the objective of keeping these emissions under control.

In yet another study, [10] included 283 Chinese cities and working through a panel dataset, results revealed that transport infrastructure was responsible for increase in urban carbon emissions and carbon intensity. This thus implied that infrastructure development undertaken to push GDP i.e. building more roads and highways without supporting environment policy measures might result in more vehicle use, urban crowding and traffic snarls thus resulting in higher emissions. Then again, [11] in their study tried to identify the drivers for energy-related CO<sub>2</sub> emissions for Brazil (*transport sector being one of the biggest stakeholder in energy related CO<sub>2</sub> emissions*) and applied the popular STIRPAT model. The study results revealed population and GDP per capita to be the main determinants. Further since the data included 27 states (both rich and poor states were included in their sample), it was seen that technology was positively related to emissions in richer states. The study thus identified, rise in technology (mainly seen as energy intensity) as a major problem.

Then, [12] also focused on infrastructure but with a different research area which was inclined towards financing of green infrastructure projects. The study results showed that how financing green finance infrastructure was different and does have a positive impact on emissions and hence provides better environment outcomes with the variable having bi-directional causality with CO<sub>2</sub> Emissions. Thus, the authors could provide answer to results obtained by some studies which showed technology as positively related to emissions i.e. not only technology for clean energy but also right funding the same was also equally important. On the other hand, [13] in their study which was based upon literature review on transport emissions reported that the transport sector was a major emitter of CO<sub>2</sub> and greenhouse gases globally and accounted for approximately 25% of total emissions. Further their research revealed that majority of studies which focused on transport emissions concentrated on quantum of emissions while only a few studies have examined the sector from the angle of efficiency and performance of transport system.

**2.1 Research Gap**

The literature review tells us that most studies on emissions in BRICS tend to focus on aggregate and not sector specific emissions. Thus, when industrial, household and transport sector emissions are combined, the results can be sometimes misleading and measures suggested tend to be more of general nature, hence sector specific (transport sector under the present study) provides a more precise understanding of relations leading to better outcomes and hence could be considered as a research gap identified for the present study. Also, from literature review it was seen that a lot of studies while developing any relation rely on simple correlation or regression models but our study decided to go beyond that by incorporating both simple as well as advanced models; panel and pooled models for capturing the dynamic relationship between GDP, population and emissions in a better manner.

**3 Methodology**

To analyze the underlying relationships, we develop four econometric models (3.1.1 to 3.1.4) using both time series and pooled data estimation techniques and adopt the following notations:

- TE<sub>G,t</sub>* denotes the growth in transport-related emissions during time period t.
- TE<sub>G,i,t</sub>* represents the same variable in a panel data context, incorporating both time series and cross-sectional dimensions.
- GDP<sub>G,t</sub>* indicates the growth in Gross Domestic Product during time period t, while *GDP<sub>G,i,t</sub>* captures GDP growth within the panel framework.
- POP<sub>G,t</sub>* refers to population growth during time period t, and *POP<sub>G,i,t</sub>* reflects population growth under the panel specification.

**3.1 Model Development**

**Model I : Time Series Model Estimation**

The estimated model is emissions due to transport as a function of GDP and Population. The time series estimation has been carried out after making all variables stationary and the model as estimated is given as eq.(i) below.

$$TE_{G,t} = \beta_1 + \beta_2 GDP_{G,t} + \beta_3 POP_{G,t} + u_t \dots\dots\dots(i)$$

**Model II: Pooled Regression Model Estimation**

The second model estimated is a pooled regression with same variables as given in eq.(i). but these are pooled for all the BRICS. Pooling improves degrees of freedom thus making the results more reliable and the model is shown as eq.(ii) below.

$$TE_{G,i,t} = \alpha_1 + \alpha_2 GDP_{G,i,t} + \alpha_3 POP_{G,i,t} + u_{i,t} \dots\dots\dots(ii)$$

### Model III: Fixed Effects (FE) Model Estimation

For fixed effects estimation, we apply within mean estimator model which takes deviations from respective means and applicable formula for variable  $TE_{G,t}$  (Country 1) is given as  $TrEG'_{1,t} = TrEG_{1,t} - \overline{TrEG}_{1,t}$ , where  $\overline{TrEG}_{1,t}$  is the mean for Transport Emissions for Country 1, while  $TrEG'_{1,t}$  is the variable obtained for Fixed effects Estimation. We do the same for other four BRICS countries and again for each of the independent variables and error term and obtain eq.(iii) which again is a similar to a pooled equation, eq.(ii) but excludes the intercept.

$$TE_{G,i,t}' = \gamma_2 GDP_{G,i,t}' + \gamma_3 POP_{G,i,t}' + u'_{i,t} \dots\dots\dots(iii)$$

### Model IV : Random Effects (RE) Estimation

For estimation of Random Effects, we modify our error term and make it a composite error term i.e.  $w_{i,t} = e_i + u_{i,t}$ ; the two components of the error term being ;  $e_i$  which is country specific cross section component and  $u_{i,t}$  the idiosyncratic error term which varies both cross sectionally and across time. The estimated model is presented as eq.(iv).

$$TE_{G,i,t} = \delta_1 + \delta_2 GDP_{G,i,t} + \delta_3 POP_{G,i,t} + w_{i,t} \dots\dots(iv)$$

## 3.2 Model Suitability and Appropriateness

Under this section we determine which of the above cross section models viz. Pooled, FE or RE i.e. eq (ii),(iii) or (iv) respectively is appropriate for our data and subsequent analysis. To this end, we carry out two tests; the first test compares Fixed Effects to Pooled estimation for which we apply a restricted-unrestricted 'F' test approach while second test compares Random Effects vs. Fixed Effects for we employ Hausman, (1978)<sup>14</sup> test. Further we retain the time series regression model (eq (i)), the reason being to bring out within country variations often ignored under cross section analysis.

### Fixed Effects vs. Pooled Estimation

We state the Null Hypothesis as fixed effects across countries are jointly equal to 0. Null gets rejected if computed 'F' Statistics (from eq. v below) > Table F The applicable formula for 'F' shall be as under:-

$$F = \frac{R_{unres}^2 - R_{res}^2 / df(res) - df(unres)}{1 - R_{unres}^2 / df(unres)} \dots(v)$$

The test computes  $R^2$  for two models, first model is termed as restricted while second model as unrestricted model. The test puts the computed  $R^2$  for two models in a ratio. For carrying out the test, we would be considering the pooled model as our restricted model while fixed effects as our unrestricted model .

### Fixed Effects (FE) vs. Random Effects (RE) Estimation

To determine which of the two models, FE or RE is appropriate for our data we apply Hausman test. The formula for Hausman compares the beta coefficient estimator obtained from Fixed and Random Effects Models i.e. eq.(iii) and eq.(iv) respectively and the applicable formula for the test (in matrix form) is given as eq. (vi) below.

$$\text{Hausman Test} = (\widehat{\beta}_{FE} - \widehat{\beta}_{RE})' [\sigma^2(\widehat{\beta}_{FE}) - \sigma^2(\widehat{\beta}_{RE})]^{-1} (\widehat{\beta}_{FE} - \widehat{\beta}_{RE}) \dots (vi)$$

where  $\widehat{\beta}_{FE}$  and  $\widehat{\beta}_{RE}$  are the vector of beta coefficients obtained from fixed and random effects models respectively while  $\sigma^2(\widehat{\beta}_{FE})$  and  $\sigma^2(\widehat{\beta}_{RE})$  are the two variance-covariance matrices of fixed and random effects model coefficients (Null Hypothesis: Accept Random Effects and Reject Fixed Effects). The test follows a Chi Square distribution and Null is Rejected (Fixed Effects Model is preferred) if computed Chi Square is statistically significant i.e. 'p'  $\leq 0.05$ .

## 4 Results and Discussion

The section provides results of the study, accompanied by supporting tables (Table 2 to 6). We begin with Table I which provides key insights derived from the time series model estimation (eq.(i)) and the table reveals that variable GDP growth (as shown by 'p' statistics) was seen significantly impacting variable Transport Emissions in a positive manner in three of the five BRICS viz. Brazil, India and S. Africa; Russia and China being the exceptions. On the other hand, the second variable included in the study; population growth was significantly impacting Transport Emissions only for India while the same was found to be insignificant for rest of the countries. On the other hand, results from pooled equation estimation (Table 3) showed that after pooling, variable GDP as pooled for all five economies was impacting Transport Emissions in a significant manner while the variable population growth was insignificant.

Furthermore, as a part of diagnostic, we checked for multicollinearity of time series ( eq. i) and pooled (eq. ii) regressions using Variance Inflation Factor ( $VIF = \frac{1}{1-R^2}$ ) and the results revealed that obtained VIF was within limits and hence required no action as the model did not suffer from problem of multicollinearity (Table 5).

Next, we move to the results obtained for Fixed Effects Estimation which was undertaken to isolate the impact of unobserved or confronting variable thereby making the coefficients of explanatory variables, consistent and efficient, result of the same is given under Table 4. Table 4 has two parts, part (i) provides the results of the Fixed

Effects Estimation while part (ii) reveals the likely impact of the confronting variable on our dependent variable Transport Emissions and is shown as cross section effects.

The results from Table 3 revealed that only GDP Growth rate was impacting Transport Emissions while population growth rate was not, the obtained results do match with pooled regression results (Table 3), however the important consideration is whether this model is superior to pooled model and the same was found to be correct when we compared  $R^2$  of both models.  $R^2$  of Pooled was 0.198276 (Table 3) and Fixed Effects: 0.348551 (Table 4). These results clearly showed that Fixed Model was a better fit. These two figures of R Square we also put in F (restricted-unrestricted) formula and the value obtained was higher than the table 'F' Statistics, proving yet again that Fixed Effects Model was superior.

Coming to the part (ii) results of Table 4 which gives the likely impact of the confronting variable on our dependent variable; Transport Emissions. The impact as seen was negative for two countries Russia and S. Africa and positive for rest. In quantum terms, the maximum impact of this variable was seen for Russia followed by China. Thus, by including this confounding variable in our analysis, we could not only make the results efficient but this also resulted in overall model improvement.

Our final set of results (Table 5) pertain to results obtained from [14] test, the test makes a comparative analysis of two Panel Models; the models compared are: Fixed Effects Model and Random Effects Model. It is important to add here that although we have discussed at length the results of Fixed Effects Model in our study, we Further although we discussed the results of Fixed Effects in detail, we avoid the results of random effects (error components model) and the reason for the same being these results are very close to Fixed Effects and difference between the two sets of results was minimal.

However, since REM works creating a composite error term which includes two terms; first being a time series and second a cross sectional component, there is a need to make a comparison with Fixed effects Model to bring which model was superior even though the difference in results was minimal. The tool applied was [14]<sup>14</sup> test and the same follows  $\chi^2$  distribution at 2df. Null : Random Effects Model is superior. The  $\chi^2$  computed value for the Hausman test was 8.55022 with a significant 'p' which enabled us to reject the Null and conclude that that appropriate model as applicable on our data and analysis was Fixed Effects.

**Table 2.** Regression results of the time series analysis (Dep Variable: Growth rate of Transport Emissions)

Country	Indep Variables	Coefficient	Probability 'p' statistics	Sig./Not Sig.
Brazil	GDP Growth rate	1.022151	0.0001	Significant
	Pop Growth Rate	0.000256	0.2177	Not Significant

<b>Russia</b>	GDP Growth rate	0.48515	0.0719	Not Significant
	Pop Growth Rate	0.000451	0.4850	Not Significant
<b>India</b>	GDP Growth rate	1.147427	0.0001	Significant
	Pop Growth Rate	0.0000028	0.0422	Significant
<b>China</b>	GDP Growth rate	1.319660	0.1188	Not Significant
	Pop Growth Rate	-0.000385	0.54408	Not Significant
<b>South Africa</b>	GDP Growth rate	1.484550	0.0002	Significant
	Pop Growth Rate	0.000312	0.1389	Not Significant

**Table 3.** Regression results of the pooled equation estimation (Dep Variable: Growth rate of Transport Emissions)

<b>Indep. Variables</b>	<b>Coefficient</b>	<b>S.E</b>	<b>Prob 'p' statistics</b>	<b>Sig./Not Sig.</b>
GDP Growth rate	0.766938	0.120021	0.0000	Significant
Pop Growth Rate	9.41E-05	0.008428	0.2455	Not Significant
R-squared			0.198276	

**Table 4. (i)** Results of the Fixed Effects Estimation (Dep Variable: Growth rate of Transport Emissions)

<b>Indep. Variables</b>	<b>Coefficient</b>	<b>S.E</b>	<b>Prob 'p' statistics</b>	<b>Sig./Not Sig.</b>
GDP Growth rate	0.416119	0.07576	0.0001	Significant
Pop Growth Rate	-0.000006	0.000224	0.7885	Not Significant
R-squared			0.348551	

**(ii)** Cross section fixed effects/Dummy Coefficients without base intercept

<b>Country</b>	<b>Effect</b>
Brazil	0.0000348
Russia	-0.000270
India	0.000128
China	0.000173

South Africa	-0.00000662
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**Table 5.** Results of Variance Inflation Factor for detecting Multicollinearity amongst variables

Type of Model	VIF Obtained	Interpretation
Time Series (Brazil)	1.025766	No Multicollinearity
Time Series (Russia)	1.305783	No Multicollinearity
Time Series (India)	1.063860	No Multicollinearity
Time Series (China)	1.084995	No Multicollinearity
Time Series (S. Africa)	1.533229	Multicollinearity within limits
Pooled Regression	1.005738	No Multicollinearity

**Table 6.** Results of the Hausman test: Fixed Vs Random Estimation

Chi Square Statistics at 2 df	Prob ('p') values	Decision regarding choice of Model
8.55022	0.0139	Fixed Effects

## 5 Conclusion and Recommendations

To conclude, the present study made an attempt to develop an econometric relation between CO<sub>2</sub> Emissions from Transport, GDP and Population for five BRICS nations (Brazil, Russia, India, China and S. Africa). The objective of the study was to determine these linkages and the extent to which economic growth and population had contributed to their emissions. To make the study more meaningful, both time series and panel regressions were applied for understanding the impact of GDP and Population variables on transport emissions. The study results showed that while growth was a leading cause of emissions across all BRICS, both individually i.e. country wise and also as a group, the same was not true for population.

Further, it was observed that in pursuit of economic growth, many BRICS nations had made substantial investments in infrastructure and large-scale development projects. Furthermore, since growth and infrastructure go hand in hand, the study therefore recommends BRICS to make all infrastructure investments sustainable to support emission reduction due to transport. Amongst other measures, the study recommends promoting low carbon transport technologies including switching to green and hybrid fuels, building roads and bridges using sustainable technologies, emphasis on circular economy all must be prioritized and strongly implemented keeping into consideration their role in emissions reduction.

Since population growth was not found to be a significant variable for the majority of BRICS nations, this opens avenues for further research to explore the underlying reasons behind this outcome. It would also be worthwhile to examine whether the results change when the indicator is replaced with urban population, as urbanization dynamics may have a more direct link with transport emissions. Future studies could therefore consider using urban population or a more refined measure such as urbanization patterns, which would make the analysis more insightful and provide a clearer understanding of these linkages. Additionally, incorporating other variables such as the quality of transport infrastructure, extent of green infrastructure, and volume of green financing is recommended to obtain a more meaningful and precise understanding of the relationships involved.

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