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IMPACT OF PRIVATE VEHICLE OWNERSHIP AND URBANIZATION ON CARBON EMISSIONS: CASE OF PAKISTAN

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ABSTRACT

A prominent contributor of emissions from carbon dioxide (CO2) is the transportation sector that accounts for nearly one-fifth of global carbon emissions. This study aims to investigate the impact of private vehicle ownership, foreign direct investments (FDI) and urbanization on CO2 emissions in Pakistan, using data from 1991 to 2020. The study considers the IPAT framework and applied the ARDL model to examine the short-term and long-term effects of private vehicle ownership, FDI, and growth in the urban population on CO2 emissions in Pakistan. The study findings showed a positive and significant nexus between CO2 emissions, private vehicle ownership, FDI, and growth in the urban population of Pakistan. It was estimated that an increase in private vehicle ownership, along with urbanization, will lead to increased CO2 emissions, and in the same way, FDI contributes to environmental degradation as it promotes more industrial activities that are usually based on fossil fuel consumption. The study, therefore, puts into perspective the need for sustainable policies to manage such environmental impacts of these factors. This provides major pointers to the policymakers in Pakistan with respect to the integration of strategies required to be counseled on the environmental consequences of private vehicle ownership, FDI, and urbanization.

Keywords: *CO2 Emissions, Urbanization, FDI, ARDL, Pakistan.*

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1. INTRODUCTION

Globally carbon dioxide (CO2) emissions have become a serious concern for environmental sustainability, having severe devastating impact on overall climate, mankind and living things on earth (Rahman et al., 2017). CO2 emissions are also considered a prime factor and an upcoming threat linked to climate change, hence standing at the forefront of current global environmental debates. Several studies that aim at unraveling the factors surrounding energy useage and CO2 emissions, the economic factors such as growth in population and transport, per capita GDP—have been sorted out behind the rising pattrens of CO2 emissions (Wang & Li, 2021; Aslam et al., 2021; Ali, Razman & Awang, 2020; Timilsina & Shrestha, 2009).

Urban population characterized by population density and land use among other factors has been found to be the important factor associated with the environmental degradation. The growing houses demand associated with rapid urbanization resulting into cutting trees and transforming the agriculture land to housing societies, and reducing the oxygen content in the air, hence causing the environmental degradation. Although the city planning and designing is also helpful in reducing the transport emissions and transport demand, however, how the different models of a city are effective in containing carbon emissions from transport remains inconclusive (Hankey & Marshall, 2010).

Besides the CO2 emissions problem is compounded by the increasing inflow of foreign direct investment (FDI) mainly in sectors directly or indirectly related to the transport industry in developing economies such as Pakistan (Khan, Weili & Khan, 2022). Though quite important for economic growth, FDI more often than not comes at the cost of environmental degradation, particularly when it brings about the expansion of industries which contribute towards higher CO2 emissions (Haq et al., 2022). In Pakistan, the FDI-carbon emissions relationship has not been hitherto adequately explored, thereby leaving a significant gap in literature regarding how economic policy might be affecting the environment (Chien, Hsu & Sadiq, 2023).

Furthermore, the transport sector has emerged worldwide as the leading sector for energy consumption and ultimately principal contributor of emissions from CO2 (Li et al., 2022; Rasool et al., 2019; Ma, Liu & Chai, 2015). Although much effort has been made to save fuel and enhance fuel economy, the CO2 emissions from transportation, specifically in developing countries have been rapidly increasing (Rehman et al., 2023).

The transportation sector holds a critical role in the contribution to CO2 emissions, particularly in developing nations like Pakistan, where swift urbanization and economic expansion have resulted in considerable alterations in transportation behaviors (Li, Li & Wang, 2022). Rasool et al. (2019) suggests that it is vital to understand the transport sector energy consumption and its impact on environmental degradation in Pakistan.

Therefore, understanding the complex relationships of economic variables with CO2 emission becomes necessary for formulating policies for mitigating environmental impact. Liu et al. (2023) argued that panel data models have proven advantageous for such analysis, as they offer better control over individual heterogeneity and provides more reliable parameter estimates. Consequently, within the framework of the IPAT and the ARDL model, the present research makes a general contribution to the debate that improves our understanding and simultaneously provides some practical insights for the

policymakers. The current study assesses the urbanization, FDI and private vehicle ownership influence on CO2 in Pakistan from 1991 to 2020.

The research aims to understand how these factors contribute to environmental degradation in a developing country context and to provide insights for policymakers to design effective environmental strategies.

The research is important in filling the literature gap by thoroughly presenting the interaction of these factors in affecting the nation's carbon footprint and therefore offering significant inputs for the policymakers involved. The findings of the present study would be very important in informing the framing of sustainable policies to balance economic growth with environmental protection when Pakistan continues to urbanize and economically develop.

The last two decades have witnessed significant economic growth and urban development in Pakistan that has ensured a manifold increase in demand for private vehicles (Khan & Majeed, 2023). However, the primary concern is that Pakistan has alarmingly high levels of air pollution (Abbas et al., 2022). Nevertheless government has put every effort to regulate and reduce the emissions through various initiatives, transportation continues to be among the largest greenhouse gas (GHG) emitting sectors. It is further aggravated by non-effective public transport systems, forcing a majority of the urban populations to rely on private vehicles for daily movement (Sohail, Ullah & Usman, 2021). This increases not only traffic congestion but also huge CO2 emissions, hence undermining efforts towards environmental sustainability (Asim et al., 2022). The increasing FDI inflow in Pakistan, mainly in sectors directly or indirectly related to the transport industry, has also compounded the issue (Khan et al., 2022). Though quite important for economic growth, FDI more often than not comes at the cost of environmental degradation, particularly when it brings about the expansion of industries which contribute towards higher CO2 emissions. Hence, this research analyzes how FDI, combined with private vehicle ownership and urbanization, affects CO2 emissions in Pakistan.

The prevailing literature on the environmental impact of urbanization and transportation within developing economies – particularly considering the case of Pakistan -- still shows a significant research gap. Most of the literature available focuses on either developed nations or rapidly industrializing countries like China and India, which have given relatively little attention towards Pakistan. This oversight is particularly concerning given Pakistan's unique socio-economic and environmental challenges, which may lead to different outcomes compared to other countries. This research fills a gap in the present literature by focusing on Pakistan, a developing country with unique socio-economic and environmental challenges. The study's application of the IPAT framework and ARDL model to the Pakistani context offers a novel contribution to the understanding of how private vehicle ownership, FDI, and urbanization interact to influence CO2 emissions. While a limited researches previously conducted regarding the role of FDI on environmental deterioration, very few have been done in the context of the transport sector in Pakistan. Therefore, this research fills this gap by analyzing how FDI, private vehicle ownership, and increasing urban population all contribute together to CO2 emissions in Pakistan. The study investigate the impact of private vehicle ownership on the CO2 in Pakistan. Moreover, it also aims to investigate the influence of FDI on CO2 in Pakistan.

2. REVIEW OF LITERATURE

Dietz and Rosa (1997) in their seminal work introduced a stochastic variation of the environmental impact, population, affluence, and technology (IPAT) model, aiming to assess the influence of these influencing factors on national CO2 emissions. The study yielded significant insights, particularly with regard to the role of affluence and population on CO2 emanations. The results indicated the presence of diseconomies of scale, suggesting that the nexus among population and CO2 is complex than previously understood. In contrast, the research revealed that the impact of affluence on CO2 emissions displayed an interesting pattern. Initially, as per-capita GDP increases, the effects of affluence on emissions exhibited growth.

A study was conducted Qingqi and Songzheng (2013) to examine the role of transportation structure on CO2 in China. The study used non-parametric regression models to examine the factors that contributes towards CO2 emissions in the transport sector. The panel data was collected from 30 Chinese provinces from 2000 to 2012. The findings of the study suggested a non-linear effect of economic growth on CO2 emissions. The findings followed an inverted "U-shaped" pattern, attributed to the initial reliance on road and air transport, followed by a shift to emission-free train transport. Additionally, the improvements in the energy efficiency exhibited a positive "U-shaped" relationship with CO2 emissions.

Yang et al (2015) also investigated the role of CO2 emissions in the transportation sector in China. The data was taken from 2000 to 2012. The study findings indicated that CO2 emissions from transportation results into significant growth during this period, with 9.29% and 8.69% annual rates, respectively. The study further concluded that there were inconsistency within regional differences in CO2 emissions. The study also revealed that various socio-economic factors, transportation development factors, and urbanization plays a crucial part in per capita CO2 discharges from transportation.

Su et al. (2022) try to explain the heterogeneity in carbon intensity from passenger transport across cities. Utilizing clustering analysis and a tree-based regression model with nine socio-economic predictors, the authors classified the 360 cities into six distinct groups based on their carbon intensity levels. The results demonstrated that higher carbon intensities were observed in affluent city groups characterized by a high share of active population. Furthermore, stepwise regression statistical technique revealed specific recommendations for each city group to effectively reduce carbon intensity. For city groups with high population share and income, constructing compact cities was found to be more effective. On the other hand, enhancing the mixed land-use degree was identified as crucial for city groups with low population share but high income. For less affluent city groups, shortening travel distance through intensified infrastructure construction emerged as a more critical measure.

Ahmad, Zhang and Liu (2020) explored the nexus between vehicle ownership and emission of CO2 in Pakistan. The study applied co-integration and causality analysis using time series data from 1971 to 2017. The findings of study concluded that increase in vehicle ownership in the long-run leads to higher CO2 emissions. Granger causality test proved the vehicle ownership granger causes CO2 emission. Thus, it was revealed in the study that the intervention in vehicle ownership by policy could be an efficient means of reduction of CO2 emissions in Pakistan.

Akram and Saleem (2017) explored the urbanization and transportation structure influence on CO2. The study employed a structural equation modeling approach, using data from various Pakistani cities. From these results, urbanization and poor infrastructure in transportation indeed contributed to high carbon emissions. This, it was argued, could be reduced by making the transport infrastructure better and facilitating public transports within urban areas. Furthermore, Ahmed and Akhtar (2021) explain in detail the connectedness of urbanization and CO2 in Pakistan using data from 1990 to 2018. Using the ARDL methodology, the results derived indicated that rapid urbanization has a significant increase in CO2 emissions, actually brought about by increased energy consumption and vehicular traffic. The paper recommended integrating sustainable urban planning with carbon reduction strategies as a mitigation measure that would help reduce the influence of urbanization on resultant emissions.

A study by Aslam, Rehman, and Imran (2019) analysed the role that public transport plays in emission reduction with regard to rapid urbanization across Pakistan. Panel data analysis was conducted concerning major Pakistani cities by considering key variables: public transport availability, urbanization rate, and emissions. It became clear that those cities which had relatively better public transport systems had lower per capita carbon emissions despite higher rates of urbanization. It was, therefore, concluded that improved public transportation would be an essential strategy for reducing carbon emissions in Pakistani cities.

Bashir, Liu, and Ahmad (2018) examine the urban policies role in reducing CO2 in Pakistani metropolises. In the research study, both policy analysis and econometric modelling approaches were used to verify whether the present-day urban policies were effectively developed. The findings from these approaches clearly indicated that the current urban policies were not in line with the goals on sustainable development and resulted in higher levels of carbon emissions. For this reason, revising urban policy to engage in sustainability measures has been suggested, particularly in transportation planning.

Khan, Jamal and Batool (2021) undertake time series data analysis for the period 1980 to 2019, using the ARDL approach. Economic growth, as estimated by this study, is increasing the number of vehicles owned, which in turn is increasing carbon emissions. On the other hand, Malik and Ali (2022) study present an analysis of the impact that sprawling has on private vehicle usage and carbon emissions within major Pakistani cities. In this study, the research methodology applied is spatial analysis, with data from a geographic information system (GIS) and supported by regression models. It can be inferred from the study that highly sprawled urbanization significantly increases dependence on private vehicles, which culminates into higher carbon emissions.

Mahmood, Furqan, and Younas (2021) conducted a study on the potential role that electric vehicles could play in reduction of carbon emission in Pakistan. Current status of using an EV was observed through application of scenario analysis supported by simulation models to estimate the impacts which EVs are going to bring about in CO2 emissions. The findings showed that the habitual adoption of an EV would greatly reduce carbon emissions in those urban areas where there is high density of vehicles. The authors have also mentioned that government policies need to be encouraging the use of EVs so as to enable achieving considerable reductions in the emissions.

Zafar and Iqbal (2021) explored the environmental impacts of motorization in Pakistan, concluding that unchecked growth in private vehicle ownership poses a serious challenge to sustainable urban development. Furthermore, Raza et al. (2022) examined policy interventions aimed at curbing CO2 emissions from the transport sector, finding that current measures are insufficient to offset the environmental damage caused by rising private vehicle ownership. Mahmood and Akhtar (2023) analysed the nexus between urbanization, vehicle ownership, and air quality, stressing the urgent need for integrated policies that address urban planning to mitigate the adverse effects on carbon emissions.
A study by Abbas et al. (2023) investigated the future growth of fossil fuel demand for transportation and associated CO2 emissions in Pakistan from 2018 to 2030. The estimates for the same have been projected by the authors using the Grey model with annual data from the year 2010 to 2018. The modeling team also developed a model to identify the drivers of fossil fuel demand under the stochastic regression IPAT framework. The study's results present a grim, increasing trend for both oil demand and carbon emissions in Pakistan at yearly growth rates of 12.68% and 11.45%. Employing FM-OLS analysis, the researchers validated the environmental Kuznets hypothesis. Whereas population growth became the most important driver for oil demand and associated CO2 emissions, technological changes hold potential for reducing oil demand and its associated emissions.

3. DATA AND METHODOLOGY

3.1. Data Sources

The study adopts quantitative research to investigate the influence of private vehicle ownership, FDI and urbanization on CO2 emissions in Pakistan. The research employed four variables, comprising one exploratory variable (CO2 emissions), and three explanatory factors (private vehicle ownership, FDI, and urban population). The time series data for CO2 emissions, FDI and urban population is derived from the World Bank's indicators, whereas private vehicle ownership data is sourced from Ministry of the Finance, Government of the Punjab website for the period 1991 to 2020. The "IPAT" framework has been utilized as a tool to undertake the environmental impact (I) resulting from population (P), affluence (A), and technology (T).
The relationships among these variables are represented by the following equations:

$$\mathbf{ln(CO2) = \beta_0 + \beta_1 * ln(Pvtvcl) + \beta_2 * ln(FDI) + \beta_3 * ln(Urbanpop) + \varepsilon}$$

Where,

β_0 represents the intercept term,
β_1, β_2, and β_3 are the coefficients of the variables,
ln(CO2) is natural logarithm of carbon dioxide (CO2) emissions,
ln(Pvtvhcl) is the natural logarithm of private vehicles ownership,
ln(FDI) is the natural logarithm of FDI
ln(Urbanpop) is the urban population, and
ε shows the residual term.

3.2. Empirical Methodology

This research examined the causal relationship using ARDL approach between CO2 emissions, FDI, urban population, and private vehicles ownership. ARDL model is well-suited for analysing the dynamics between variables, particularly in the context of panel data (Pesaran et al., 2001). Furthermore, the ARDL technique is chosen because it allows for the estimation of both short-run and long-run equilibrium relationships (Nkoro & Uko, 2016).

3.2.1 Unit Root Test

The unit root test is employed to assess whether a time series is non-stationary and to detect the presence of a unit root. If a unit root exists in a time series, then that series is stochastic and its mean and variance or other statistical features change over time which can lead to spurious regression results. This feature is very useful for analyzing a time series because most of the statistical models assume that the underlying time series is stationary.

Unit root tests, such as the ADF test, are essential tools in econometric analysis, as they help determine the appropriate transformation or modeling approach to ensure valid statistical inference and reliable forecasting. It's null hypothesis states that the variable has a unit root, which is tantamount to the variable being non-stationary.

According to Chang and Park (2002), in order for a variable to be considered stationary at the appropriate significance level, the ADF t-statistic needs to be more negative than the critical value. If the p-value is less than the stated level of significance, then one can reject the null hypothesis. The equation $\Delta Yt = \alpha + \beta t + \gamma Yt - 1 + \delta 1 \Delta Yt - 1$ is used, where α represents the intercept, β represents the slope, and γ is the lag order, assuming a random walk model by setting $\alpha = 0$ and $\beta = 1$.

3.2.2 Short and Long-term Elasticity

The equation for the study model can be represented as follows:

$$\Delta CO2t = \alpha_0 + \sum(1i\ \Delta logCO2t\text{-}i) + \sum(2i\ \Delta logFDI\text{-}i) + \sum(3i\ \Delta logUrbanpopt\text{-}i) + \sum(4i\ \Delta logPvtvcl\text{-}i) + \lambda 2 logCO2t\text{-}i + \lambda 3 logFDIt\text{-}i + \lambda 4 logUrbanpopt\text{-}i + \lambda 5 logPvtvcl\text{-}i + \varepsilon_t$$

In the equation above, the symbol Δ indicates the difference, α_0 represents the intercept, and ε_t represents the error term, Σ is error correlation dynamics, λ represents the long-run association among understudied variables. It also incorporates changes in the variables over time. The selection of lag length is based on criteria such as the Akaike information criterion (AIC).

Once the long-run association is established, the next stage involves checking the model stability, which is achieved through the error correction model (ECM). It is represented as follows:

$$\Delta CO2t = \alpha 0 + \sum(1i\ \Delta logCO2t\text{-}i) + \sum(2i\ \Delta logFDIt\text{-}i) + \sum(3i\ \Delta logUurbanpopt\text{-}i) + \sum(4i\ \Delta logPvtvcl\text{-}i) + \lambda 2logCO2t\text{-}i + \lambda 3logFDIt\text{-}i + \lambda 4logUrbanpopt\text{-}i + \lambda 5logPvtvcl\text{-}i + \eta ECTt\text{-}1 + \varepsilon t$$

Here, η is the growth speed to attain equilibrium level over different periods. ECT_{t-i} refers to the error correction term which helps to assess how rapidly the system adjusts towards its long-run equilibrium after experiencing short-term deviations.

4. FINDINGS OF THE STUDY

4.1. Descriptive Statistics

The descriptive statistics provides statistical summaries of four variables: LnCO2 (logarithm of carbon emissions), LnFDI (logarithm of foreign direct investment), LnPvtvcl (logarithm of private vehicle ownership), and LnUrbanpop (logarithm of urban population). Table 1 shows that the average value of LNCO2 across the 30 observations was 11.68, LnFDI has mean of 20.83, LnPvtvcl has mean of 8.65 and LnUrbanpop has mean of 17.88. The median values are close to the means, indicating that the data distributions are relatively symmetrical. The minimum and maximum values show the data range for each variable, with LnCO2 and LnFDI showing a wide range compared to LnPvtvcl and LnUrbanpop. Furthermore, standard deviation measures the amount of dispersion from the mean, indicating greater variability in LnFDI and LnPvtvcl compared to LnCO2 and LnUrbanpop. Similarly, skewness and kurtosis values are closer to zero, suggesting that the distributions are approximately normal for each variable. Jarque-Bera test is used to check data normality. The p-value associated with Jarque-Bera test indicates that all variables have high p-values (above 0.05 significance level) which means that data is likely normally distributed. The significance level is 0.01 or 1%.

Table 1: Descriptive Statistics

	Carbon Emissions (CO2)	**Foreign Direct Investment (FDI)**	**Private Ownership (Pvtvcl)**	**Urban population (Urbanpop)**
Mean	11.687	20.838	8.654	17.882
Median	11.750	20.920	8.661	17.910
Maximum	12.199	22.444	10.276	18.251
Minimum	11.007	19.370	7.267	17.419
Std. Dev.	0.332	0.874	0.890	0.253
Skewness	-0.277	0.045	0.232	-0.288
Kurtosis	2.038	2.006	1.946	1.858
Jarque-Bera	1.542	1.243	1.658	2.044
Probability	0.462	0.536	0.436	0.359

4.2. Unit Root Test

ADF test is one of the most widely employed statistical procedures for examining the unit root presence in a time series. ADF test incorporates lagged differences of the predicted variable to control for higher-order serial correlation, thereby enhancing its robustness. The null hypothesis of the ADF test posits that "the variable contains a unit root." If the

computed ADF t-statistic is less than the critical value, the null hypothesis is rejected. However, it is important to note that if variables are found to be stationary at the second difference, ARDL model cannot be applied. This is because the ARDL framework, as proposed by Pesaran et al. (2001), relies on bound testing, which assumes that variables are either I(0) or I(1), but not I(2).

Table 2: Unit Root Test

Variables	T-statistics	p-value	Decision
CO2	-4.546	0.0012*	I(I)
FDI	-4.390	0.0018*	I(I)
PrivateVehicle Ownership	-4.985	0.0004*	I(I)
Urban Population	-3.020	0.0459*	I(0)

*show 1% significance level

Table 2 provides the results of the unit root test. The test concludes that the variables CO2, FDI, and private vehicle ownership are non-stationary at their levels as the p-value is less than 0.01 significance level but become stationary after first differencing, indicated by I(1). However, the urban population variable is stationary at level, indicated by I(0).

4.3. Bound Test

Pesaran et al. (2001) bound testing approach is a cointegration method to examine the existence of the long-term (cointegrating) in the model. Table 3 indicates that the F-statistic (3.787) value is above the upper bound at the 10% significance level, which shows that evidence of a long-term relationship among the variables. However, as the significance level becomes more stringent (5%, 2.5%, 1%), the evidence weakens, making the conclusion less robust at those levels. Thus, we can conclude that a long-term relationship likely exists, particularly at a 10% significance level.

Table 3: Bound Test for Cointegration

Null hypotheses: no long relationship exists.		
Test statistics	**Value**	**k**
F-statistics	3.787	3
Critical Value Bounds		
Significance	**10 bounds**	**11 bounds**
10%	2.72	3.77
5%	3.23	4.35
2.5%	3.69	4.89
1%	4.29	5.61

4.3.1. ARDL Test

Table 4 presents the output results for the cointegrating form and the long-run coefficients from an Error Correction Model (ECM). The cointegrating form captures the short-term relationship between the variables, while the long-run coefficients represent the estimated long-term relationship. The short-term dynamics show that changes in FDI, private vehicle ownership, and urban population significantly impact the dependent variable. Besides,

ECM confirms that deviations is corrected over time from the long-term equilibrium. The long-run coefficients describe the relationship between the variables over the long-term after controlling for cointegration. These coefficients indicate the impact of each explanatory variable (LnFDI, LnPVtvcl, and LnUrbanpop) on the dependent variable (LnCO2) in the long run. The coefficients provide insights into the direction and magnitude of the relationship among these variables and CO2 emissions.

Table 4: ARDL Test

Cointegrating form variable				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
D(LnFDI)	0.041757	0.012238	3.412044	0.0023*
D(LnPvtvcl)	0.081027	0.037725	2.147806	0.0420**
D(LnUrbanpop)	0.405926	0.182289	2.226824	0.0356**
CointEq(-1)	-0.643161	0.143827	-4.471771	0.0002*
Long run coefficients				
LnFDI	0.064924	0.017907	3.625728	0.0013*
LnPvtvcl	0.125982	0.055076	2.287396	0.0313**
LnUrbanpop	0.631142	0.207758	3.037880	0.0057*
C	-2.017038	3.183039	-0.633683	0.5323

* $p < 0.001$; ** $p < 0.05$; *** $p < 0.10$

Hence, the equation can be written as:
Cointeq = LnCO2 - (0.0649*LnFDI + 0.1260*LnPvtvcl + 0.6311*LnUrbanpop - 2.0170)

The estimated long-term relationship suggest that FDI has a long run influence on CO2 emissions in Pakistan. The reason behind that many developed countries having the stringent environmental standards have shifted the affluent production plants and technology to the developing economies as they have the less stringent environmental standards. Recently, coal power plants are set up by China under CPEC project at Qadirabad, Pakistan, and it is observed that environmental quality is much affected in the nearby areas. Another factor is private vehicle ownership that has a detriminantal influence on CO2 emissions. Estimated long-term relationship suggest that results show 1 percent increase in private vehicle ownership has a 12 percent increase in CO2 at the 5% level. Lastly, the coefficient of urban population is turned out to be 0.6311. It implies that a one-unit increase in urban population is associated with larger 63 percent increase in carbon emissions, assuming the other variables in the model are held constant. This is significant at the 1% level.

4.3.2. Diagnosis Tests

When conducting an ARDL model analysis, it is crucial to perform various diagnostic tests for model robustness and validity. These diagnostic tests are essential for validating ARDL model. The findings of diagnostic tests (autocorrelation, heteroskedasticity, multi-collinearity, and Ramsey RESET test) indicate that no potential issues exists, and that our

findings are reliable and model appropriately reflects the underlying data-generating process. Moreover, model stability test (CUSUM and CUSUMSQ) plots also lies within the 5% significance level, hence model is stable over the sample period.

5. CONCLUSION

The study is conducted to analyze the relationship of CO2 emissions with three independent variables in Pakistan: urban population, FDI, and the private vehicles. An attempt has been made in this research to use the framework of "IPAT" to see the environmental impact. The econometric model adopted for the research is the ARDL model, which is appropriate to be estimated for variables that are either level I(0) or I(1) or both simultaneously. The result shows a long-term association among CO2 emission, FDI, urban population, and a number of private vehicles. It was found that FDI, private vehicles, and the urban population have a positive statistically significant effect on CO2 emission in the long-run. The study recommends that sustainable policies and strategies are essential for mitigating the environmental impact of increasing FDI, urbanization, and private vehicle ownership in Pakistan. The study is limited to the analysis of data from 1991 to 2020, which may not fully capture recent trends or future developments in Pakistan's transportation and urbanization patterns. Additionally, the study focuses primarily on carbon emissions and does not consider other environmental impacts such as air quality or water pollution. Future research could magnify the scope to contain a wider array of environmental indicators and consider more recent data.

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