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RESEARCH ARTICLE

Modeling the impact of transport energy consumption on CO_2 emission in Pakistan: Evidence from ARDL approach

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Abstract

The objective of this research is to examine the relationship between transport energy consumption, economic growth, and carbon dioxide emission (CO_2) from transport sector incorporating foreign direct investment and urbanization. This study is carried out in Pakistan by applying autoregressive distributive lag (ARDL) and vector error correction model (VECM) over 1990–2015. The empirical results indicate a strong significant impact of transport energy consumption on CO_2 emissions from the transportation sector. Furthermore, foreign direct investment also contributes to CO_2 emission. Interestingly, the impact of economic growth and urbanization on transport CO_2 emission is statistically insignificant. Overall, transport energy consumption and foreign direct investment are not environmentally friendly. The new empirical evidence from this study provides a complete picture of the determinants of emissions from the transport sector and these novel findings not only help to advance the existing literature but also can be of special interest to the country's policymakers. So, we urge that government needs to focus on promoting the energy efficient means of transportation to improve environmental quality with less adverse influence on economic growth.

Keywords CO_2 emission · Transport energy consumption · FDI · Pakistan · ARDL

Introduction

Transport infrastructure is a major tool to promote the organization and economic growth in the region. Transport sector influences all aspects of human life, education, research, entertainment, trade to manufacturing, culture, and defense. Countries around the globe realize its strength in economic growth and transforming resources into knowledge and communication (Mohmand et al. 2016; Subhra and Nath 2017). Growth is the main factor, which influences CO_2 emission (Andreoni and Galmarini 2012; Sobrino and Monzon 2014). Transport CO_2 emissions are intertwined with economic growth, and nonlinear effect of economic growth on CO_2 emissions is consistent (Xu and Lin 2015).

Despite the importance of transport infrastructure in economic growth, it also contributes to lower environmental quality. Road traffic is the largest contributor to the carbon footprint of the transport sector, and the reduction of transport has become one of the main objectives of sustainable transport policy (Sobrino and Monzon 2014). For instance, Chandran and Tang (2013) probe that transport energy consumption constitutes carbon dioxide and analyze that CO_2 emission varies due to change in weather. Also, online shopping causes to reduce carbon dioxide (CO_2) emissions from passenger transport (Liu et al. 2016; Smidfelt Rosqvist and Hiselius 2016). Road transport also contributes to CO_2 emissions. Also, both traffic for cargo and passenger reduced 4.3% of CO_2 emission during the evolution of commercial air traffic (Solís and Sheinbaum 2013; Amizadeh et al. 2016). In the same way, Shahbaz et al. (2015) conclude that road transportation enhances CO_2 emission in Tunisia. Timilsina and Shrestha (2009) have concluded that growth, population, and energy intensity are the main elements for motivating CO_2 emission from the transport sector in Asia. For instance, Duan et al. (2015) argue that over the last few decades, transport sector actively participates in the growing carbon emissions. Lin and Xie (2014) argue that carbon

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dioxide emissions will reach 1024.24 million tons (Mt) in 2020 in China; although its reduction potential will be 304.59 and 422.99 Mt under modest emission-reduction scenario and advanced emission-reduction scenario, respectively. The residents travel demand increased significantly. The results show that motor vehicle emissions are one of the main sources of air pollution, thus affecting the health of residents (HE and QIU 2016). The transport sector is second the largest energy consumer in the world and highly contributes to the economy more specifically in developing countries. However, despite the role of the transport sector in economic growth, it is a threat to global warming and counted as second largest carbon emitter in the world. Recently, transport infrastructure gets immense attention in the literature. To contribute to this field of research, the current paper begins to understand the ambiguous relationship between transport energy consumption and environmental quality, that is, we investigate the impact of important transport-related factors such as economic growth, foreign direct investment (FDI), and urbanization on CO_2 emissions. This is the first attempt to add potential factor related to transport in the existing body of knowledge related to transport energy consumption and CO_2 emissions.

The debate on energy, transport, and sustainable development is related to the discussion of sustainable development priorities and climate change. The main concern is the adverse effects of oil consumption, including greenhouse gas (GHG) emissions and air pollution. The transport industry is the world's second-largest energy consumer. It consumes more than 30% of the world's total energy consumption. In developing countries, the transport sector has made a significant contribution to the economy. However, while the transport sector has played a role in economic growth, it also poses a threat to global warming and is listed as the world's second-largest carbon emitter. Therefore, transport infrastructure gets immense attention in the literature in recent past. Only a few studies regarding the energy–CO_2 emission nexus have focused on energy consumption from the transport sector and its impact on CO_2 emissions. For instance, Chandran and Tang (2013) suggest that economic growth and transport energy consumption significantly influence CO_2 emissions in the long run, whereas FDI has no impact on CO_2 emission in ASEAN-5 countries. Liddle and Lung (2013) determine causality running between transport energy consumption and economic growth in long run. In a study of Tunisia, Shahbaz et al. (2015) found that both road infrastructure and transport energy consumption cause to increase pollution by emitting CO_2 emission. Furthermore, bidirectional causality is found between transport energy consumption and CO_2 emissions. The bidirectional causality is also found between transport value-added and CO_2 emissions. Talbi (2017) argues that road transport mainly based on fossil fuel which is the leading contributor to transport sector's CO_2 emissions. Achour and Belloumi 2016) conclude that road transport-related energy consumption, transport of carbon dioxide emissions, and total capital formation cause road infrastructure. In a study for Saudi Arabia, Alshehry and Belloumi (2017) disagree with the existence of inverse U-shaped relationship between transport CO_2 emissions and economic growth.

To summarize, prior studies mainly focus on aggregate and disaggregate energy consumption and its impact on CO_2 emissions. However, little attention has given to transport energy consumption and its influence on CO_2 emissions. Also, the conclusion drawn from these studies is inconclusive. Using time series data of Pakistan, this study is a first attempt to analyze the impact of transport energy consumption, economic growth, and CO_2 emission incorporating urbanization and foreign direct investment (FDI) of Pakistan. Energy saving and carbon dioxide emission reduction get attention worldwide. Pakistan is currently in the stage of industrialization and urbanization, which is characterized by rapid growth of energy consumption. Pakistan's transport industry is highly energy-consuming and polluting. The rapid growth of transport, no high-quality fuel, and triggered problem of air pollution resist the solution to the problem. The surge in demand for energy leads to increasing use of coal (an average of 13 per year). The increase in oil, crude oil, electricity, and natural gas has an adverse impact on climate change (Danish et al. 2017a). Pakistan is an emerging economy; the transport sector consumes much energy, such as oil consumption (Shahbaz et al. 2017). Pakistan climate change is ranked among the highest in the world regarding vulnerability. Energy and transport sectors are the major sources of emission and together making up half of the national total. Presently, CO_2 emissions increase at the rate of 6% per year and will reach 400 Mt of CO_2 equivalent (per year) by 2030 if the business-as-usual scenario remains intact (UNDP 2015). The transport sector, because of the growing industrialization and urbanization of Pakistan, is one of the fastest growing sectors regarding output, energy consumption, and CO_2 emission. Its current performance and future outlook have the potential to leave behind problems related to the global issues of energy security and environmental sustainability (Lin and Ahmad 2016).

The present work contributes to the existing literature in numerous ways. First, to best of our knowledge, this study is the first attempt to investigate the impact of transport energy consumption on CO_2 emission in Pakistan-specific scenario incorporating FDI, urbanization, and economic growth. We add FDI and urbanization as a control variable to the transport energy and emission model because of technology and investment transfer in shape of FDI may influance the envrionment. We address this issue as greenhouse effect is a crucial concern from a policy perspective, particularly about CO_2 emission from transpor sector. In the previous literature, the role of transport in determining carbon dioxide emissions was not practicable, although it is becoming increasingly important in Pakistan. The rapid growth of transport, no high-quality fuel, and triggered problem of air pollution resist the solution to the problem in the case of Pakistan. The surge in demand for energy leads to increasing use of coal (an average of 13 per year). The increasing use of petroleum, crude oil, electricity, and natural gas in the transport sector is the main cause of negative climate change (Danish et al. 2017a). Identifying key drivers of carbon dioxide emissions is critical to the development of effective environmental and emission reduction policies. Second, earlier studies regarding the long-run impact of transport energy consumption and CO_2 emission have used total CO_2 emission to measure environmental quality. However, in this study, we use CO_2 emission from transport sector to measure the environmental quality. Lastly, we have added some important transport-related factor such as urbanization and FDI in a multivariate framework to avoid specification bias. It solves the issue of the specification and produces reliable and consistent empirical result. It would also be helpful for policymakers to formulate comprehensive environmental policy for sustainable economic development and considerably add to better long-run environmental performance. We perform ARDL methods to ascertain long-run and short-run dynamics. VECM Granger causality approach is applied to the direction of causality.

The rest of the paper is organized as follows: "Model specification, data sources, and econometric methodology" describes the data source and methodology. "Results analysis and discussion" explains the results and discussion and the concluding remarks are given in "Conclusion and policy implications."

Model specification, data sources, and econometric methodology

Data sources

The present research work has gathered data from world development indicator (World Bank) and economic survey of Pakistan over the time span 1990–2015. CO_2 emission from transport sector is used to measure environmental quality. Economic growth is measured as GDP per capita (constant 2010 US Dollar). Transport energy consumption is measured in tons of oil equivalent. FDI has measured the net inflows of investment percentage of GDP. Urbanization is calculated urban population in the percentage of total population. The data on CO_2 emission, GDP, FDI, and urbanization are extracted from the database of world development indicator. The data on transport energy consumption is extracted from the international energy agency. For detail about variable and description, please refer to Table 1 of the study. Figure 1 shows the trends in CO_2 emission from transport sector, transport energy consumption, FDI, economic growth, and urban population.

Model specification

This study focuses on the relationship between CO_2 emissions for the transport sector, consumption for the transportation sector, FDI, and per capita real GDP in specific scenario of Pakistan; so employed the following model:

$$LogCO_{2t} = \beta_0 + \beta_1(LogGDP_t) + \beta_2(LogTRE_t) + \beta_3(LogFDI_t) + \beta_4(LogURB_t) + \omega_o \qquad (1)$$

where CO_2 is the emission of CO_2 from the transport sector, GDP is the economic growth; TRE shows the transport energy consumption, FDI indicates the foreign direct investment, and URB is the urbanization. ω_0 is the error term, and t is the period, $t = 1, 2, \ldots n$.

Economic growth, transport-related energy consumption, and CO_2 emission are strongly linked. Transport activities are essential for economic and social development. Nevertheless, the transport sector has also shown the fastest growth in energy consumption (Pablo-Romero et al. 2017). The transport sector is the major energy consumer in Pakistan particularly fossil fuel consumption. Urban density is growing at an average annual growth rate of 1.69%. Urbanized kilometers increase with the growth of urban density and spatial distribution of households and activities behind the urban roads (Talbi 2017). That is why we use urbanization as a control variable in our study. FDI is another control variable we use in the study; FDI is found to have an easing impact on the environment. Trade liberalization measures as export to GDP influences the environment.

Econometric strategy

For the analysis of time series data, several econometric approaches have been used to estimate long-run and short-run dynamics. We use ARDL-bound testing approach proposed by Pesaran et al. (2001) to ascertain the impact of transport energy consumption and economic growth and transport CO_2 emission in the presence of FDI and urbanization. ARDL approach is preferred due to some of its advantages. First, ARDL is the best estimation technique in the case of a sample of data. ARDL specification is equivalent to standard error correction model from a statistical point of view. However, standard errors it produces are likely to be different. Therefore, the estimates calculate through ARDL are unbiased. ARDL approach calculates both long-run and short-run estimates at once through linear transformation technique. ARDL is considered to be the most suitable approach in the case of stationary level independent of $I(0)$ or $I(1)$. So in our case, data sample is small, so ARDL is the best choice to estimate long-run and short-run elasticities. The unrestricted

Table 1 Variable name, symbols, description, and data source

Variable	Symbols	Description	Data source
Carbon emission	CO_2	CO_2 emissions from transport contain emissions from the combustion of fuel for all transport activity, regardless of the sector. This includes domestic aviation, domestic navigation, road, rail, and pipeline transport (World Bank).	World Bank
Transport energy consumption	TRE	It includes energy consumption from fossil fuels and gas consumption.	International energy agency
Economic growth	GDP	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.	World Bank
Foreign direct investment	FDI	Foreign direct investment is the net inflows of investment to acquire a lasting management interest. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors and is divided by GDP (World Bank).	World Bank
Urbanization	URB	Urban population refers to people living in urban areas as defined by national statistical offices. The data are collected and smoothed by United Nations Population Division (World Bank).	World Bank

error correction model (UECM) is followed, and the empirical equation for Eq. (1) is given below:

$$\begin{aligned}\Delta LogCO_{2t} = {} & \varphi_0 + \theta_1 LogTEC_{t-1} + \theta_2 LogGDP_{t-1} \\ & + \theta_3 LogFDI_{t-1} + \theta_4 LogURB_{t-1} \\ & + \sum_{i=1}^{p} \pi_1 \Delta(LogCO_2)_{t-i} \\ & + \sum_{j=0}^{p} \pi_2 \Delta LogTEC_{t-i} \\ & + \sum_{j=0}^{p} \pi_3 \Delta LogGDP_{t-i} \\ & + \sum_{j=0}^{p} \pi_4 \Delta LogFDI_{t-i} \\ & + \sum_{j=0}^{p} \pi_5 \Delta LogURB_{t-i} + \omega_{2t}. \end{aligned} \quad (2)$$

Δ is the lag difference operator of the variable and P is the present lag length. The first step before applying ARDL is an investigation of cointegration among underlying variables. The null of the hypothesis of which is to be tested is ($H_0 \neq \theta_1 \neq \theta_2 \neq \theta_3 \neq \theta_4 \neq 0$) against the alternative hypothesis which is ($H_0 = \theta_1 = \theta_2 = \theta_3 = \theta_4 = 0$). To test the hypothesis, we calculate F value independent of the order of integration. The F value exceeds the upper bound limit directed toward rejection of the null hypothesis of no cointegration and F value below the lower limit indication of no-cointegration. Further results will be considered inconclusive if F value lies between upper and lower limits. For upper lower and bound limits, we rely on the bound testing values (Narayan 2005). The short-run coefficients are obtained by the estimates of . The coefficients of θ_1, θ_2, θ_3, and θ_4 estimate the long-run dynamics of Eq. (2). Based on the methodology of Danish et al. (2017a), to check the robustness of the ARDL model, we have used alternative long-run estimation technique such as fully modified least square (FMOLS) method, dynamic ordinary least square method (DOLS), and canonical cointegration regression (CCR). Further, for reliability and validity of estimate produced by ARDL approach, we have used several diagnostic tests such as LM and Durban Watson (DW) tests for autocorrelation and autoregressive conditional heteroskedasticity (ARCH) test for heteroskedasticity.

Results analysis and discussion

Unit root analysis

To estimate long-run and short-run dynamics between economic variable, it is imperative to check the level of stationary. Otherwise, the results would be biased and unreliable in the presence of stationarity. Another reason is that any variable integrated with order 2 restrict us to use ARDL-bound testing approach. For this purpose, the present study relies on Augmented Ducky Fuller, Phillips Pesaran, and DF-GLD test statistic. The reason behind using three tests is to confirm the level of stationary at different levels. The results of unit root test are reported in Table 2. After analyzing the results, we infer that the null hypothesis cannot be rejected at level but a first difference. So, it suggests that we can pursue cointegration approach in this study.

Bound testing results

Once we confirm that none of the variables are integrated at the second difference. Next, we move to find the cointegration. For this, we estimate F statistic by applying bound testing approach; however, before bounding testing approach, it is essential to find the lag length. We choose lag length 2 for the study under VAR lag length selection criteria. After confirmation of the optimal lag length, next we confirm the cointegration among variables of interest. For the purpose,

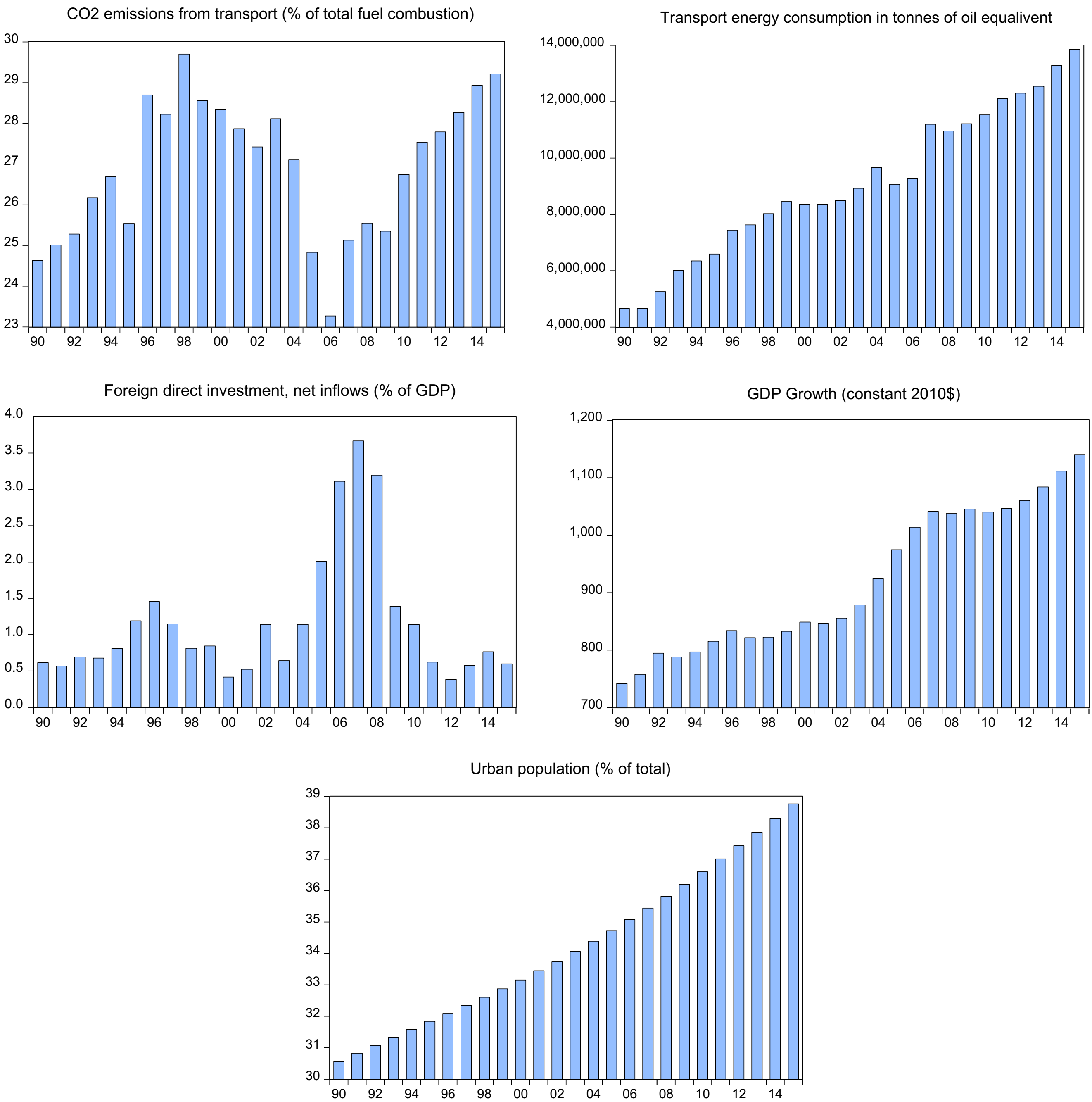


Fig. 1 Trends in CO_2 emission from transport sector, transport energy consumption, FDI, economic growth, and urban population of Pakistan

Wald statistic is used. For lag length, we choose Akaike information criteria (AIC) most suitable for the study. Results in Table 3 show that we reject the null of the hypothesis of cointegration for the all the equations.

ARDL long-run and short-run dynamics

The cointegration results suggest a long-run relationship between variables of interest. The results of a long run and short run are reported in Table 4. The results indicate that the coefficient of total transport energy consumption is positive and significantly elastic in the central point of the sample. The outcome shadows our expectation, and the transport energy consumption causes to pollute the environmental quality in the country. The result is similar to Chandran and Tang (2013) and Shahbaz et al. (2015), and they conclude the same result. Further, the similar results are acquired by (Saboori et al. 2014) for single country analysis for 27 OECD country. Also, Alshehry and Belloumi (2017) estimate the similar result for Saudi Arabia. Comparatively, results of our study are more interesting such as we calculate environmental quality by CO_2 emission from transport sector instead of using overall

Table 2 Results of unit root tests

Variables	ADF test statistic		PP test statistic		DF-GLS test statistic	
	Level	First difference	Level	First difference	Level	First difference
Log CO_2	− 2.5832	− 3.0058[b]	− 2.3320	− 2.9414[b]	0.0024	− 2.9615[a]
Log TEC	− 1.5910	− 4.6266[a]	− 3.0120	− 5.2242[a]	− .0206	− 4.4238[a]
Log GDP	0.6791	− 3.3383[b]	− 0.2176	− 3.0660[b]	0.1355	− 3.2890[a]
Log FDI	− 3.6246	− 4.1422[b]	− 1.9987	− 4.1310[a]	− .0532	− 4.2071[a]
Log URB	2.7978	− 5.6306[a]	12.778	− 4.5341[a]	− 7.2726	− 2.3102[b]

[a] Level of rejection at 1%

[b] Level of rejection at 5%

[c] Level of rejection at 10%

CO_2 emission. The plausible reason is that expansion in number of vehicles demand cuases to energy consumption. Rapidly growing modes of transport, no high-quality fuels, in turn, have raised air pollution problems and resisted climate change (Danish et al. 2017a). Fossil fuels power the vast majority of road vehicles in Pakistan. Controlling the transport energy consumption from fossil fuel is the most immediate and proper solution to mitigate CO_2 emission. The road infrastructure, the number of vehicles on the road, and the transport energy consumption are interrelated. For instance, Pakistan's quest for rapid economic growth compromises the sustainability of the environment and it will be an alarming situation for the economic, health, and social life of the people of the country.

Turn into the estimation of the effect of economic growth on CO_2 emission, the long-run results in Table 4 infer that economic growth has an insignificant impact on economic growth. This finding deviates from the existing studies due to several reasons. One plausible reason may be that in Pakistan, government focuses only toward the economic growth not transport energy consumption. The other reason may be that unlike other studies, we have used the proxy of CO_2 emission from transport sector instead of using total carbon emission. It implies that economic growth does not contribute to carbon emission from transport sector but not the total CO_2 emission. For instance, Danish et al. (2017a, b) have tested economic growth with total CO_2 emission by testing environmental Kuznets curve (EKC) in Pakistan and the study infers the positive

Table 3 Results of bound F statistic and diagnostic tests

Equation	Bound testing approach			Diagnostic tests		
	Lag order	F value	Decision	$\chi^2 - \text{Reset}$	$\chi^2 - \text{LM}$	$\chi^2 - \text{ARCH}$
$\log CO_2 = F(\log GDP, \log EC, \log FDI, \log URB)$	(1, 0, 2, 2, 2)	4.641[a]	Reject null hypothesis of no cointegration	0.9805	1.2508	1.9219
$\log GDP = F(\log CO_2, \log EC, \log FDI, \log URB)$	(1, 2, 0, 2, 0)	3.504[b]	Reject null hypothesis of no cointegration	0.0445	1.7558	1.7636
$\log EC = F(\log GDP, \log CO_2, \log FDI, \log URB)$	(2, 2, 0, 0, 1)	8.512[a]	Reject null hypothesis of no cointegration	0.2393	2.4244	0.4071
$\log FDI = F(\log GDP, \log EC, \log CO_2, \log URB)$	(2, 2, 0, 2, 1)	4.164[a]	Reject null hypothesis of no cointegration	0.9286	1.3329	0.1594
$\log URB = F(\log GDP, \log EC, \log CO_2, \log FDI)$	(1, 1, 2, 2, 1)	5.123[a]	Reject null hypothesis of no cointegration	0.7879	0.4734	0.0036
Critical value bounds						
Significance	I_0 bound	I_1 bound				
10%	2.2	3.09				
5%	2.56	3.49				
2.5%	2.88	3.87				
1%	3.29	4.37				

Value in parenthesis shows the probabilities values

[a] Level of rejection at 1%

[b] Level of rejection at 5%

[c] Level of rejection at 10%

Table 4 Results of long-run and short-run estimates

Variable	Coefficient	Std. error	*t* statistic	Prob.
Long-run estimates				
log*TEC*	0.6781[b]	0.300498	2.256663	0.0435
log*GDP*	− 1.0786	0.971970	− 1.109708	0.2889
log*FDI*	0.1139[b]	0.042279	2.694945	0.0195
log*URB*	0.4188	2.511324	0.166803	0.8703
C	5.3780[a]	1.677218	3.206551	0.0075
Short-run estimates				
log*TEC*	0.0022	0.004015	0.567630	0.5808
log*GDP*	0.8783[b]	0.363071	2.419293	0.0324
log*FDI*	0.0176	0.016797	1.051073	0.3139
log*URB*	95.256	60.509389	1.574236	0.1414
CointEq(− 1)	− 0.4649[c]	0.215505	− 2.157622	0.0519
Diagnostic test				
R^2	0.998234			
DW	2.170085			
F statistic	616.5269			
Prob(*F* statistic)	0.000000			
χ^2 − Reset	0.9805 [0.3479]			
χ^2 − LM	1.2508 [0.3275]			
χ^2 − ARCH	1.9219 [0.1590]			

Value in parenthesis shows the probabilities values

[a] Level of rejection at 1%

[b] Level of rejection at 5%

[c] Level of rejection at 10%

relationship between economic growth and total CO_2 emission. So, we infer that economic growth in Pakistan is only favorable for the transportation sector. Another possible reason may be that mostly the national transport sector like metro bus projects is fuel-subsidized and the green bus projects are environmental friendly. This suggests the promotion of mega bus projects like metro bus all around the country. At the same time result is insignificant with (Danish and Baloch 2017) as they find neagtive impact of economic growth on environmental degardation in case of Pakistan.

About the control variable FDI, we infer that the influence of FDI on transport CO_2 emission is positive and significant. It implies that FDI speeds up the rate of emission of CO_2 in the transport sector to pollute the environment. For the upgrading of road transport, Pakistan mostly relies on FDI, and the majority of the FDI inflows are targeted at road infrastructure. So, it may be the reason that technology transfer for the purpose to expand and upgrade transport network more particularly for road network is not environmental friendly. The results are similar to the findings of Chandran and Tang (2013), who find the positive impact of FDI on CO_2 emission in Malaysia, Singapore, and Thailand.

Moving on to urbanization, the impact of urbanization on CO_2 emission is insignificant. In the process of urbanization transfer, the labor force from agriculture to industrial and service sector in urban areas and the shift in production to commercial goods from in-house production accelerate the transportation activities. The increase in transportation activities consumes more energy and consequently emission of CO_2 increases. Another reason is that it speeded the development of public and private transport, which consumes additional energy and results in decreasing of environmental quality. An increase in urban population may cause more transportation of products and raw materials from rural areas to urban areas which may boost the scale of production to meet the need and demand of the migrated population. Similarly, with the increase in intercity transport along with city sprawl and commuter traffic, the private transports are increasing from day to day globally (Zhu et al. 2017). This increase in transport can improve infrastructure in the form of construction facilities such as electricity and road network enhancements, sewage disposal and uncontaminated water supply, and sanitation and drainage system. The maintenance and construction of infrastructure may consume more energy which also increases CO_2 emission (Arvin et al.

Table 5 Results of FMOLS, DOLS, and CCR analysis (robust check)

Variable	Fully modified least square (FMOLS)		Dynamic ordinary least square (DOLS)		Canonical cointegrating regression (CCR)	
	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
log*TEC*	0.513864[a]	0.0050	0.542512	0.0040	0.501447	0.0096
log*GDP*	0.246355	0.7109	0.490486	0.5143	0.154869	0.8330
log*FDI*	0.084249[b]	0.0138	0.062544	0.0922	0.091074	0.0228
log*URB*	1.602465	0.3349	1.186615	0.5123	1.789892	0.3442
Constant	1.312533[c]	0.0006	1.027948	0.0054	1.380946	0.0005

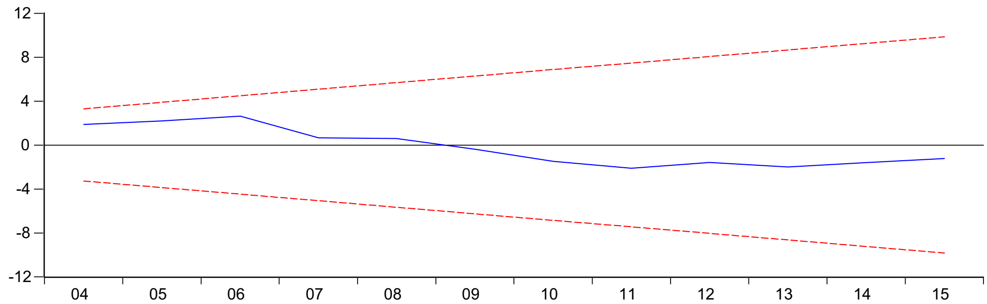
Value in parenthesis shows the probability values

[a] Level of rejection at 1%

[b] Level of rejection at 5%

[c] Level of rejection at 10%

Fig. 2 Results of CUMSUM at 5% level of significance. The area between red lines is the area for rejection of null hypothesis



2015). Thus, the rapid increase in population requires more production of goods and services which need more energy consumption and CO_2 emission rise. This can be attributed to technology innovation, market integration, as well as to human capital. Due to all of these factors, urbanization may cause degrade environmental quality in the future; so, policymaker in Pakistan should keep in view the negative role of urbanization, as urbanization is a long-run process and takes time to appear its influence on environmental quality.

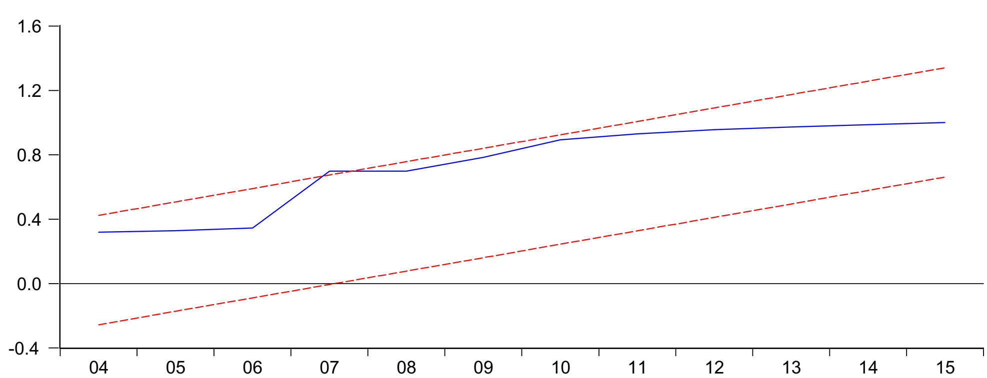
Turn into the short-run dynamics is shown in Table 5. The estimate of short run suggests different results than long-run estimates. In the short run, economic growth has a significant positive impact on transport CO_2 emission, while transport energy consumption, FDI, and urbanization have an insignificant impact on transport CO_2 emission. The variation of long-run estimates from short-run estimates suggests different policy suggestions for the long-term plan as vision 2025–2050 and short plan such as vision 2025.

Robust analysis

In this study, we also check robustness by applying three alternative techniques such as FMOLS, DOLS, and CCR to estimate Eq. (2) following Baek (2016) and Danish et al. (2017a). Table 5 presents that impact of GDP on CO_2 emission is insignificant. Additionally, findings approve that transport energy consumption accelerates CO_2 emission. Also, FDI and urbanization have a significant and positive impact on CO_2 emission. The results from all the three different methods confirm our results estimated by ARDL-bound testing approach. Furthermore, to see endogeneity, lack of structural invariance, and for the stability of model, we perform CUSUM of residual and CUMSUMsq of residual tests and results drawn are shown in Figs. 1 and 2, respectively. The results suggest that the blue line lies well between red lines which indicate the significance level which directs that results are stable (Fig. 3). Further, we use χ^2-Reset, χ^2 – LM, and χ^2-ARCH to see the presence of autocorrelation and heteroscedasticity and the results are noted at the bottom of Table 4. The results show that transport energy consumption, FDI, economic growth, and urbanization explain variation in transport CO_2 emission in the absence of autocorrelation and heteroscedasticity. Therefore, results of the study are reliable and can be used for policy implication.

The existence of long-run estimates is an indication for at least one-way causal relationship among variable of interest. To check causal relationship in the present study, we rely on VECM Granger causality approach. The estimation of VECM Granger causality is a two-step procedure. First, we to find error correction term by running the single regression. Next, we estimate error correction model in order to get long-run causality. In the second step, we calculate Wald statistic for estimation of the short-run causal relationship among core variable of the study. In the model among a single-period lagged error correction term (ECT_{t-1}), because of Engle and Granger

Fig. 3 Results of CUMSUMsq at 5% level of significance. The area between red lines is the area for rejection of null hypothesis



(1987) caution that if the series are integrated of order one, the cointegration VAR estimation in first difference will be misleading. Thus, the augmented Granger causality test with ECM is formulated below:

$$\begin{pmatrix} \log CO_2 \\ \log GDP \\ \log TEC \\ \log FDI \\ \log URB \end{pmatrix} = \begin{pmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \end{pmatrix} + \begin{pmatrix} \beta_{11K} & \beta_{12K} & \beta_{13K} & \beta_{14K} & \beta_{15K} & \beta_{16K} \\ \beta_{21K} & \beta_{22K} & \beta_{23K} & \beta_{24K} & \beta_{25K} & \beta_{26K} \\ \beta_{31K} & \beta_{32K} & \beta_{33K} & \beta_{34K} & \beta_{35K} & \beta_{36K} \\ \beta_{41K} & \beta_{42K} & \beta_{43K} & \beta_{44K} & \beta_{45K} & \beta_{46K} \\ \beta_{51K} & \beta_{52K} & \beta_{53K} & \beta_{54K} & \beta_{55K} & \beta_{56K} \end{pmatrix} \begin{pmatrix} \Delta \log CO_{2it} \\ \Delta \log GDP_{it} \\ \Delta \log TEC_{it} \\ \Delta \log FDI_{it} \\ \Delta \log URB_{it} \end{pmatrix} + \begin{pmatrix} \rho_1 \\ \rho_2 \\ \rho_3 \\ \rho_4 \\ \rho_5 \end{pmatrix} ecm_{it-1} + \begin{pmatrix} \vartheta_1 \\ \vartheta_2 \\ \vartheta_3 \\ \vartheta_4 \\ \vartheta_5 \end{pmatrix}. \quad (3)$$

t shows the period (1990–2015), i denotes $i = 1, 2, 3 \ldots 25$, ecm_{it-1} is the lagged error correction term and the stochastic error term, and ω_{it} indicates the residual term.

The results of causality analysis are reported in Table 6. The long-run causal relationship indicates that bidirectional causality only exists between FDI and economic growth. In the feedback, the hypothesis is confirmed between transport energy consumption and CO_2 emission from the transport sector. The results are consistent with the findings of Saboori et al. (2014) for OECD countries and Alshehry and Belloumi (2017) detect bidirectional causality between transport energy consumption and CO_2 emission. Moreover, unidirectional causality is running from CO_2 emission to economic growth. Furthermore, bidirectional causality is detected between urbanization and CO_2 and between FDI and economic growth.

Variance decomposition analysis

From Table 7, it is indicated that 51.79% of carbon emission is explained by an outer factor beyond the model of this study. The share of GDP, FDI, and transport energy consumption is 12.87, 15.96, and 15% and the share of urbanization is negligible. Similarly, the share of a GDP due to its shock is 47%. The contribution of CO_2 emission in a GDP is 26.62%, whereas variation due to FDI and urbanization is negligible; however, the share of transport energy consumption is 19.43%. The share of energy consumption due to its own shock is 32.20%. The share of CO_2 emission in transport energy consumption is 7.39%. The percentage of GDP, FDI, and urbanization is 33.54, 71.2, and 9.65%, respectively. The contribution of FDI due to its own shock is 24.29. The share of CO_2, transport energy consumption, and GDP is 28.24, 14.74, and 30.38, respectively. Furthermore, the share of urbanization is negligible. Lastly, the share of urbanization due to its own shock is 6.1%. The contribution of CO_2 emission, transport energy consumption, and GDP is 17.21, 25.97, and 46.71, respectively. However, the share of FDI in urbanization is negligible.

Impulse response function

Turn into impulse response function which is the substitute for variance decomposition analysis. The impulse response function explains the reaction of independent variables (see

Table 6 Results of long-run and short-run causality analysis

Variables	Short run causality Wald statistic					Long run-causality (t statistic)
	$\Delta \log CO_2$	$\Delta \log TEC$	$\Delta \log GDP$	$\Delta \log FDI$	$\Delta \log URB$	ecm_{t-1}
$\log CO_2$	–	2.9760[a]	2.8448 [b]	0.7327	− 2.0914[c]	− 1.2879
		[0.0078]	[0.0104]	[0.4727]	[0.0502]	[0.2132]
$\log TEC$	2.9273 [a]	–	− 1.7196	− 0.1226	0.2909	− 1.6707
	[0.0086]		[0.1017]	[0.9037]	[0.7742]	[0.1112]
$\log GDP$	1.6337	− 0.5427	–	2.7762[b]	1.7085	− 3.2345[a]
	[0.1188]	[0.5936]		[0.0120]	[0.1038]	[0.0044]
$\log FDI$	1.1358	− 0.2013	2.3206[b]	–	− 0.5687	− 3.8009[a]
	[0.2701]	[0.8426]	[0.0316]		[0.5762]	[0.0012]
$\log URB$	− 2.3429 [b]	0.5949	1.2997	− 0.335179	–	0.2920
	[0.0302]	[0.5589]	[0.2092]	[0.7412]		[0.7734]

Value in parenthesis shows the probabilities values

[a] Level of rejection at 1%

[b] Level of rejection at 5%

[c] Level of rejection at 10%

Table 7 Variance decomposition analysis

Period	S.E.	logCO_2	log*TEC*	log*GDP*	log*FDI*	log*URB*
Variance decomposition of logCO_2						
1	0.008947	100.0000	0.000000	0.000000	0.000000	0.000000
2	0.014446	80.93408	6.658941	1.554370	7.874128	2.978483
3	0.020720	57.26386	17.15481	3.632381	19.18066	2.768293
4	0.023915	56.68049	17.93389	3.294094	19.65741	2.434115
5	0.025718	58.51181	17.33553	4.031854	17.55747	2.563327
6	0.026885	56.97237	16.63531	6.808231	16.76848	2.815614
7	0.027672	54.65746	15.77820	9.724802	16.71709	3.122450
8	0.028187	52.93377	15.25756	11.96879	16.26478	3.575102
9	0.028469	52.07284	15.11166	12.88263	15.96105	3.971818
10	0.028629	51.79286	15.10069	12.87911	15.96204	4.265296
Variance decomposition of log*TEC*						
1	0.013177	3.833816	96.16618	0.000000	0.000000	0.000000
2	0.015359	2.841854	72.17245	0.266475	6.442120	18.27711
3	0.019872	3.533115	44.09565	22.22504	16.64578	13.50042
4	0.021848	4.428062	37.34133	32.63702	14.42438	11.16921
5	0.022575	6.436749	35.75324	33.51188	13.57639	10.72174
6	0.023255	6.093369	34.12240	34.08714	15.27930	10.41779
7	0.023809	5.996580	32.61609	34.72162	16.71796	9.947752
8	0.023894	6.131296	32.60022	34.57459	16.81656	9.877330
9	0.024108	6.526695	32.33612	34.02746	17.38985	9.719877
10	0.024290	7.393680	32.20425	33.54999	17.20106	9.651020
Variance decomposition of log*GDP*						
1	0.005071	7.055919	0.860540	92.08354	0.000000	0.000000
2	0.008817	26.35778	16.25289	54.02600	3.079377	0.283949
3	0.011108	32.46949	17.93786	42.38227	6.774188	0.436199
4	0.012341	34.79699	22.73916	34.35098	7.757763	0.355097
5	0.012873	34.24812	24.63909	33.42369	7.358622	0.330479
6	0.013431	31.93441	23.03900	37.73546	6.954131	0.336997
7	0.014125	28.87570	20.88509	43.11522	6.818586	0.305400
8	0.014599	27.22908	19.70373	46.12094	6.617531	0.328721
9	0.014768	26.69139	19.43978	46.96056	6.542138	0.366130
10	0.014802	26.62693	19.43151	47.00355	6.525285	0.412721
Variance decomposition of log*FDI*						
1	0.160545	5.971293	2.739694	30.43308	60.85593	0.000000
2	0.208485	16.62224	7.866752	32.32941	41.39783	1.783772
3	0.245954	25.54499	14.34204	28.88705	29.83271	1.393211
4	0.267751	32.45290	14.60930	24.76469	26.82736	1.345757
5	0.280161	33.02726	14.34690	24.36639	26.84281	1.416638
6	0.287733	31.37112	14.47488	26.28632	25.94678	1.920903
7	0.292377	30.39790	14.04313	28.36747	25.28012	1.911369
8	0.299525	28.96470	14.49736	30.07411	24.61149	1.852340
9	0.302640	28.42563	14.77769	30.61850	24.10753	2.070649
10	0.303851	28.24621	14.74742	30.38806	24.29331	2.324998
Variance decomposition of log*URB*						
1	3.25E−05	5.218636	28.74550	7.198450	14.60335	44.23406
2	7.86E−05	9.701247	34.06363	15.31452	13.75819	27.16241
3	0.000136	11.29907	37.15548	19.73841	11.09846	20.70858
4	0.000203	12.65970	36.47676	24.78094	8.966135	17.11647

Table 7 (continued)

Period	S.E.	logCO_2	log*TEC*	log*GDP*	log*FDI*	log*URB*
5	0.000277	13.46331	34.13725	30.56270	7.722034	14.11470
6	0.000358	13.82779	31.90432	35.79995	6.799982	11.66796
7	0.000442	14.25325	29.89813	40.00914	6.012874	9.826600
8	0.000528	14.94998	28.15023	43.23547	5.317581	8.346746
9	0.000615	15.93311	26.85304	45.44587	4.649936	7.118035
10	0.000701	17.21593	25.97505	46.71185	3.996676	6.100493

Fig. 4). The findings of impulse response function reveal that CO_2 emission rises due to forecast error stemming from energy crises. This shows that carbon emission rises due to rising in transport energy consumption. The forecast error in economic growth enhances carbon emission. The response of FDI in CO_2 emission arises with the passage of time. The forecast error in FDI due to CO_2 emission, urbanization, economic growth, and energy consumption remains constant as shown in Fig. 4. The response of urbanization due to CO_2 emission is increasing whereas due to FDI, economic growth and transport energy consumption are increasing. The response of CO_2 emission in transport energy consumption is decreasing. The response of the urbanization and economic growth in transport energy consumption is increasing.

Conclusion and policy implications

This research investigates the relationship between transport energy consumption, economic growth, and carbon dioxide emissions to account FDI and urbanization in Pakistan. For the purpose, we perform a family of econometric series over

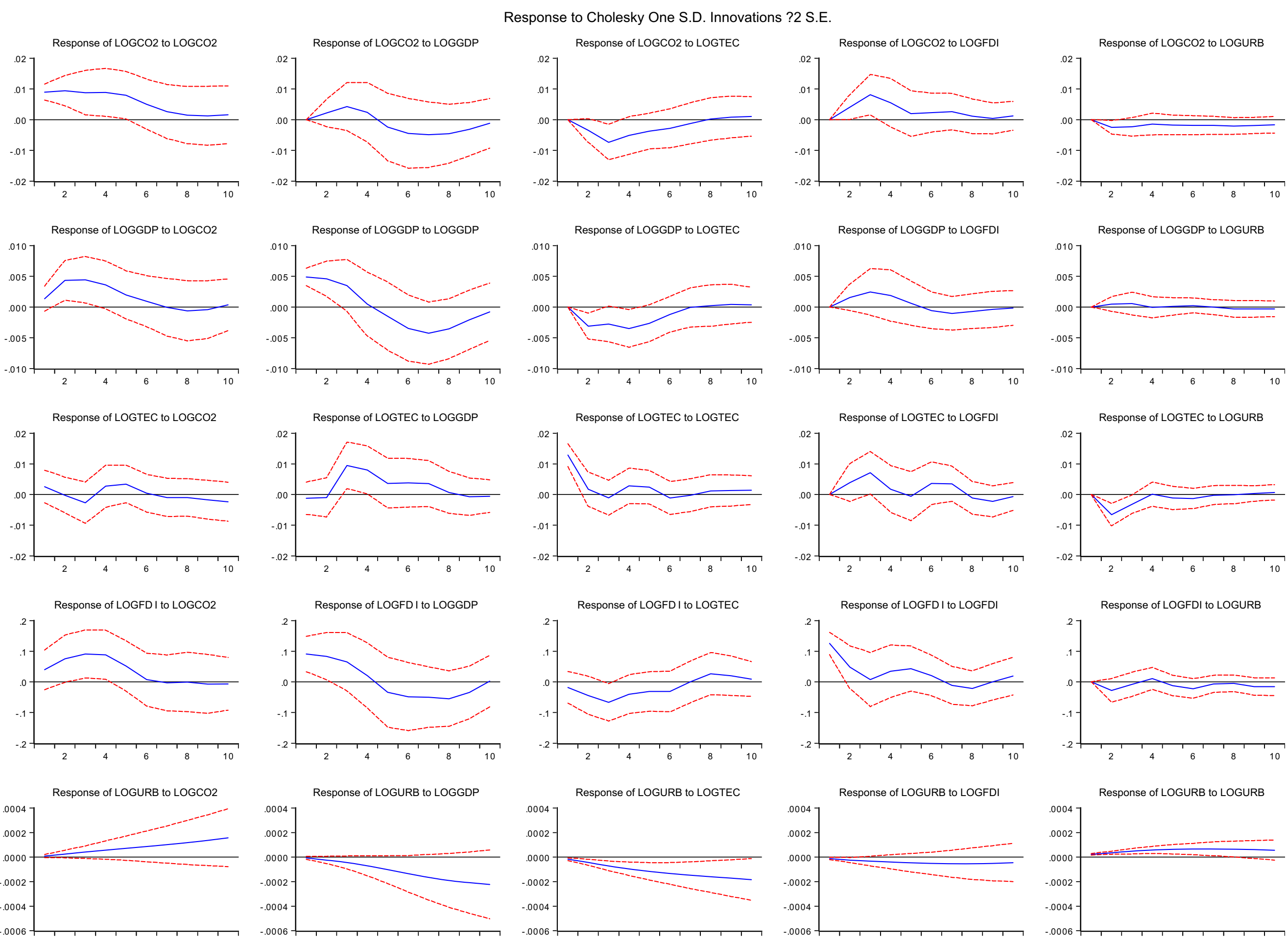


Fig. 4 Impulse response function

the time 1990–2015. The robustness of the model is checked by using three alternative techniques, i.e., FMOLS, DOLS, and CCR approaches. For detection of causality, we rely on VECM Granger causality followed by innovative accounting approach. From estimation, we observe some interesting findings. First, transport energy consumption causes to increase in emission of CO_2 and degrades environmental quality. Additionally, FDI significantly accelerates the rate of CO_2 emission from the transport sector, which degrades environmental quality. Second and more interestingly, economic growth and urbanization both have an insignificant impact on CO_2 emission from transport as against our expectations.

The empirical findings suggest a linear relationship between transport energy consumption and environmental degradation, as we expected. Mass transit busses and trucks are the major vehicles on roads, which consume most of the fossil fuels and over half of the oil is consumed in the transport sector of Pakistan (UNDP 2015). Fossil fuel has adverse impact on environmental quality. Excessive burning of fossil fuel in the major sectors of the economy, e.g., transport sector, depletes the environmental quality. So, we suggest based on the estimation of present work that government needs to cut the number of vehicles which is threatening the environmental sustainability. Mass bus transit scheme should be converted into green transportation more particularly in big cities. As other studies also suggests that the government desires to endorse CNG-loaded transport vehicles to lessen fossil fuel consumption to support the country's human-friendly environment (Danish et al. 2017a), we also urge that government should launch mass green bus transit scheme in all big cities of the country to reduce the dependency on private vehicles, which mostly run on diesel and oil products. Also, the externality effect may be responsible for high levels of transport energy consumption in Pakistan. This means that third parties can positively affect road transport energy consumption. In the case of Pakistan, the external effects of rail transport can be taken into account, since rail transport is an energy-efficient means of transport. The situation of rail transport is worsening due to the ignorance of the government. Pakistan railway performance is poor and the people of the country prefer to travel by roads. Poor performance of the railway is the main problem of long-term decline in profits, rising operating costs, investment, and system dichotomy and governance issues. As the population continues to grow, the railroad transport burden continues to develop and as a result, Pakistan's road transport energy increased. As we discussed above, road transport and energy consumption are not effective and environmentally friendly. Therefore, we urge the government of Pakistan to focus on rail transportation to reduce the burden and dependency on road transport. At first sight, one would anticipate that the reduction in the consumption of fossil fuels can be achieved through improving the infrastructure for the public transport sector, such as the ride on public transport which can be made more convenient, luxurious, and attractive for all class of users and similar to the use of private cars powered by fossil fuels.

Additionally, the government needs to focus on FDI particularly in the transport section. As indicated by our econometric estimation, most of the FDI is worsening the environmental quality. The government needs to restrict the transfer of technology which pollutes the environment by imposing dumping duties. Another way to control transferring of polluting technology is the time of agreement government needs to include the condition that guest country or company would shift clean energy technology that may help to reduce pollution.

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