Check for updates

Effects of transport–carbon intensity, transportation, and economic complexity on environmental and health expenditures

Zahid Hussain[1] · Bihizi Marcel[2] · Abdul Majeed[3] ·
Raymondo Sandra Marcelline Tsimisaraka[3]

Abstract

Health and the environment are complex components of the countries, influenced by several factors, especially transport, and economics. Thus, this paper assesses the role of transportation and economic complexity in the environment and public health for the Organization for Economic Co-operation Development (OECD) countries from 2001 to 2020. This study also focuses on the relationship between transport and economic complexity with environmental and healthcare expenditures. Precisely, transport and economic activities stimulate healthcare expenditures through multiple channels. The current study employs the STIRPAT model to investigate the association with transportation, economic complexity, transport–carbon intensity, and healthcare expenditure. Besides, the current research confirms the plausible cross-sectional dependency across countries, and it adopts a second-generation technique. Analytical findings suggest that transportation-carbon intensity is positively and significantly associated with healthcare expenditures. Healthcare and transport–household expenditures increase transport–carbon intensity (TCI) by 75% and 45%, respectively, in the long run. In the contrast, TCI and transport–household expenditures have also a remarkable impact on healthcare expenditures and are estimated approximately 95% in the long run. Moreover, economic growth also upsurges TCI and healthcare expenditures through multiple economic activities. Besides, transport–household expenditures (THE) drastically impact transport–carbon intensity and healthcare expenditures (HEX) through passenger traffic (PTF). Diagnostic upshots unveil that the joint effect of THE and PTF increases TCI and HEX by 4 and 3%, respectively. Finally, findings recommend some policy implications and future research directions for the countries based on empirical outcomes. Countries should regulate economic activities to reduce transport carbon emissions.

✉ Zahid Hussain
zahiduibe@yahoo.com; zahid@qlu.edu.cn

Extended author information available on the last page of the article

Springer

1 Introduction

Health and environment are multifaceted facets of each economy and have received great attention globally in recent days, especially from environmental and health scholars and at international summits. Thus, several factors affect health and environment-oriented transport (transport–carbon intensity), particularly transport and economic (de Albornoz et al., 2022; Heidari et al., 2022; Kumar & Dua, 2022; Wan et al., 2022). More precisely, because of drastic changes in transportation and economic structure, the public's health and environment are substantially deteriorating. Besides, climate change and global warming are also adversely affecting health and environmental quality. In order to address the environmental issues concern over their harmful effects on health and economy, the Paris Agreement on climate change has been conducted by the largest countries to improve the environment's quality (Radmehr et al., 2021; Yang et al., 2021a, b).

Figure 1 illustrates that worldwide carbon emissions are increasing due to several economic and non-economic activities. This indicates regions and countries are drastically releasing carbon emissions into the atmosphere via multiple sectors, especially transportation. Thus, the transport sector is also significantly contributing to worldwide carbon emissions. Facts indicate that Europe excluded and included, the European Union-27, the USA, and China regions are found to have had higher amounts of carbon emissions in the last century, which is an alarming situation for the global environment.

Previous studies, e.g., Abbasi et al. (2023a, b) and Abbasi and Erdebilli (2023), also focused on the issue of carbon emissions released by distinctive sectors in different countries. Moreover, their arguments emphasize that green environmental approaches such as a green closed-loop supply chain network can combat environmental issues. Besides, Abbasi et al. (2021; 2022a, b) also measure the performance of sustainable supply chain responses to non-economic issues (COVID-19-related diseases), which can improve the environmental quality.
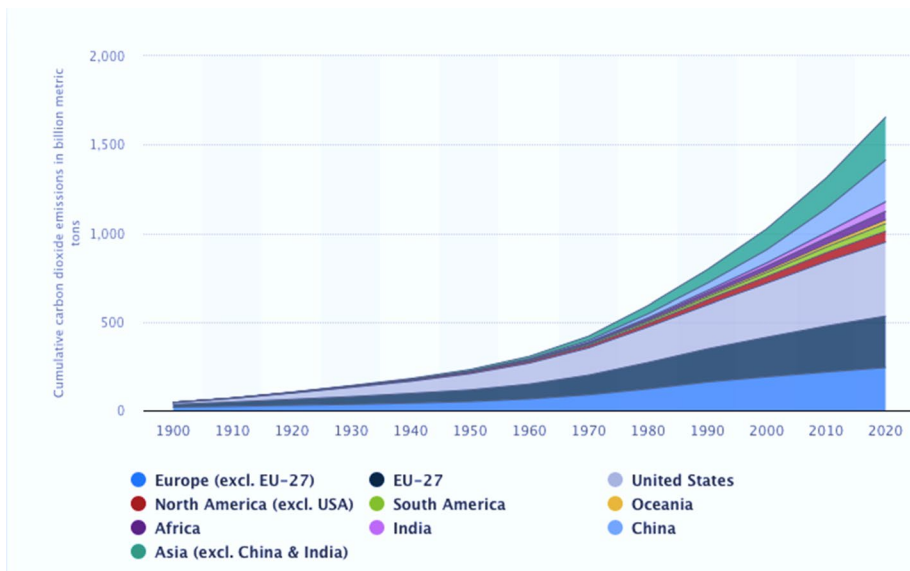

Fig. 1 Cumulative CO2 emissions by region (in billion tons). Source: www.statista.com

A World Health Organization report illustrates that free-carbon development-related investment via institutional rules and regulations has been considered a mega investment project in the health sector. Precisely, a diverse social and economic environment stimulates the demand for public health that is instantly correlated with healthcare expenditures. Furthermore, the majority of the population has been breathing unhygienic air. Global warming and air pollution have exaggerated different diseases or viruses, i.e., lung cancer, strokes, heart disease, and respiratory diseases. As a result, enormous numbers of individuals die from many diseases and viruses (e.g., lung cancer, paralysis, etc., each year). Abbasi & Choukolaei, 2023). According to the report of the World Health Organization (WHO, 2019b), approximately 2.5 billion deaths are projected to occur each year from 2030 to 2050 because of diarrhea, malaria, high temperatures, and malnutrition.

Transportation is a crucial factor for the environment and public health. It does substantially affect the public health and environment by releasing greenhouse gas emissions into the atmosphere that pollute the environment and spread viruses in the human body. The fact that the transport sector contributes to greenhouse gas emissions around 24% globally indicates that human activities, e.g., passenger and freight traffic, power transportation from burning fossil fuels, industrialization, electricity production, and international trade, are the leading emissions contributors to rising ecological mortification (Hussain et al., 2021; Jin et al., 2022; Konc et al., 2021). Passenger and freight traffic release hazardous toxins into the atmosphere through different anthropogenetic processes, which can have unfavorable consequences on public health (Shahadin et al., 2018). However, green networks can positively affect the environment by reducing carbon emissions (Abbasi et al., 2022a). On the contrary, transport–household expenditure is also an important influencer for the environment because it causes pollution. More precisely, spending on personal or household vehicles stimulates the traffic level for multiple purposes (especially family-oriented travel or trips), which causes the release of carbon dioxide and PM2.5 air pollution into the atmosphere (Choudhari et al., 2022; Dingil & Esztergár-Kiss, 2021; Liu et al., 2022; Ozkan & Atli, 2021; Simic et al., 2022).

In addition, economic complexity also plays a vital role in public health and the environment. It provides a new mode of regime where the people learn from new innovations or methods by managing their resources, skills, and knowledge. Thus, economic complexity generates new economic activities by which countries require more and more natural (energy, water, and land) and human resources (skills, labor, and capital) in order to innovate. Under such circumstances, human health- and environmental-oriented greenhouse gases are released via transportation, industrialization, and globalization (Yang et al., 2021a, 2021b). Consequently, emissions and expenditures are likely to increase over the time period. Therefore, countries should concentrate on equal distribution and allocation of given resources in order to combat public health and environmental detrimental effects over economies. Furthermore, policymakers must focus on achieving resource equilibrium in order to improve public health, particularly in healthcare. Although associations among the resources can have dual effects, for instance, carbon dioxide emissions and air pollution released from transportation become evidence of lung disorders, and consequently, the expenses of individuals are increased.

Healthcare expenditures (HEX) are important factors of economic gross domestic product (GDP), and previous studies have researched that a positive relationship between healthcare and economic growth exists. Moreover, a continued rise in economic activity encourages higher investment in human capital. Consequently, healthcare expenditures could rise, boosting economic growth and improving environmental quality (Nathaniel et al., 2021; Raghupathi & Raghupathi, 2020).

The World Economic Forum report demonstrates that approximately one-third of global healthcare expenditures would be transferred to developing countries from developed countries in 2022. The effect of anthropogenetic emissions such as transport–carbon intensity on public health has received great attention. This statement argues that greenhouse emissions do not only reduce the manufacture of healthcare goods, but nonetheless enhance the economic expenditures of healthcare goods in the presence of diseases (Khan et al., 2022; López-Casasnovas & Soley-Bori, 2014). A rise in healthcare expenditures is a crucial subject for industrialized nations due to augmentation of facilities related to health (Geue et al., 2014). Considering the association between economic growth and distinctive health spending: (1) environmental economic theoretical notion explains that precautionary healthcare expenditures substantially reduce environmental degradation. (2) Healthcare expenditures increase human capital and economic growth. More specifically, we seek estimation of the hypothesis: Does the transport–carbon intensity affect healthcare expenditures? Recently, several research scholars have taken serious description of environmental and health issues in the context of scarce resources. For instance, air pollution negatively affects health and well-being and also causes diseases of the brain, heart, and lungs, increasing healthcare expenditures. Health-oriented spending on the commodities stimulate traffic activities, which may release carbon dioxide emissions into the atmosphere.

Thus, this article chooses the sample countries of the members of the Organization for Economic Co-operation and Development (OECD) due to some reasons: First, they spend a larger amount on healthcare expenditures. Second, these countries are responsible for producing 24% of the global carbon dioxide emissions from the transport sector (Hussain et al., 2021). So, it is essential to examine the influence of transport–carbon intensity on healthcare expenditures to recommend appropriate strategy suggestions. An unexpected pandemic has been considered a challenge for the universal healthcare system. COVID-19 has severely threatened the public's health and the economy, an indication of persistent discrimination in the health sector. Scholars who are concerned about environmental and public health issues are paying close attention to transportation as a key part of their research. Transportation is a complicated subject that has a long-term impact on the world's economic systems (Herberholz & Phuntsho, 2021; Isphording & Pestel, 2021).

Unlike arrangements, they illuminate that the association between transportation and health can be predicted (Jiang, 2022; Saelens et al., 2022). First, passenger and freight traffic can have a substantial effect on health by traveling via road, rail, and air routes. Second, transportation can influence the logistics and trade system with respect to the distance of a country. As a result, changes in parameters that can have an impact on human health may occur. Third, a rise in demand for healthcare goods and services requires them to be moved from one country to another due to health issues (e.g., the COVID-19 vaccine and surgical kits) via various transport modes. This increases the greenhouse emissions, and this has a negative impact on health. Economic complexity is being perceived as an important source of long-term economic development based on the management of resources, skills, knowledge, and research and development concentrations with the goal of new inventions (Peters & deBeche-Adams, 2022; Rasendran et al., 2022). In developing countries, economic growth and mobility have led to a dramatic decline in environmental quality, which has increased healthcare costs. The following probes may be raised, depending on the level of concern: Economic complexity has a direct impact on healthcare policy. Second, how does transportation shape healthcare expenditures? Third, how do healthcare expenditures contribute to carbon dioxide emissions released by the transport sector? Fourth, is there any relationship between economic complexity, transportation, transport–carbon intensity, and healthcare expenditures?

This research motivates by making some interesting contributions (as per our best knowledge), which are the following: Former studies did not examine the dynamical association between healthcare expenditures and the quality of life, transport–carbon intensity, economic growth, transportation (passenger and freight traffic, and transport–household expenditures), and economic complexity by regressing on the STIRPAT framework. Furthermore, two functions related to human health and the environment are also examined in a single equation. Current academic work utilizes transport–carbon intensity as a proxy for the environment, which is employed by some scholars due to its distinctive nature. Third, we also investigate the joint effect of transport–household expenditure and passenger traffic on healthcare expenditure and transport–carbon intensity. Fourth, current research also examines the causal effects of the transport–carbon effect and healthcare expenditure for 35 OECD countries. Lastly, a second-generation method is employed to estimate the relationship between public health, transport–carbon intensity, transportation, and economic complexity.

Finally, we organize the study's structure as follows: Sect. 2 provides the related studies concerning the nexus between healthcare expenditures, the environment, and transportation. Section 3 documents the data description and model specification, including methodology. Section 4 provides the empirical results and discussions on both health and environmental functions. Lastly, we document the conclusion part and recommend the policy implications in the last section.

2 Literature review

Environmental and health issues are the most critical challenges for economies because of continuous economic growth, transportation, urban population growth, and so on. Therefore, several experts documented the findings on hotly debated topics, which are pathways to develop new directions in environment and health. Thus, numerous research papers emphasized the association between the environment (carbon emissions), healthcare expenditure, economic complexity, and economic growth. This study presents the related studies in the following subsection: (1) environment–transportation nexus; (2) environment–economic complexity nexus; (3) transportation–healthcare expenditures nexus; and (4) economic complexity–healthcare expenditures nexus.

2.1 Environment–transportation nexus

There have been a substantial number of studies on the relationship between transport and the environment that have received great attention in recent days. For instance, Hussain et al. (2021) investigate that transportation, e.g., traffic movements (road, railway, and air), has significant effects on the environment. Furthermore, a rise in traffic volume pollutes the environment by releasing carbon emissions into the atmosphere in OECD countries. Subsequently, Churchill et al. (2021) also examined the upshot of transportation on CO2 emissions for developed countries. Results debate whether transportation drastically enhances carbon dioxide emissions by 0.4%. More interestingly, the time-varying correlation between CO2 emissions and transportation remained positive through the Second World War and up until.

Additionally, Rokicki et al. (2022) and Sun et al. (2021) conducted the studies on the relationship between the environment (CO2 emissions) and transportation (e.g., passenger

and freight traffic by road) for 22 European countries. The findings indicate that the transportation sector accounts for 27% of total CO2 emissions. Road transport emissions, in particular, are entirely driven by the consumption of petrol. Consequently, energy use became a crucial factor in deteriorating the environment through carbon dioxide emissions. Furthermore, Pani et al. (2021) stated that freight traffic contributes significantly to greenhouse gas emissions in emerging and industrialized economies. The reason for this is that truck vehicles transport shipments, which results in an increase in energy demand; as a result, carbon dioxide emissions are emitted into the atmosphere, degrading the quality of the environment. Likewise, another study, e.g., Cardenete and López-Cabaco (2021), argues that cargo (freight transport) is a rational operational variable, which means that this factor contributes more than 30 percent of other modes of transport to Spain's carbon dioxide emissions.

Li et al. (2022a, b) also investigate the nexus between the environment and the transport sector. They argue that the transportation sector is a critical source of carbon emissions, which cause the environment to deteriorate over time. Besides, the repressive upshot of energy efficiency on carbon emissions is increasing in the transport sector as it uses unit of energy to produce unit of gross domestic product. For instance, carbohydrate emissions could be reduced by 0.818% when energy efficiency is below the threshold value of 0.473 million/t. In contrast, a unit change in energy efficiency causes a decline of 0.926% in carbon emissions. Zhao et al. (2022) debate that the transport sector is quite significant in consuming fossil fuels. As a result, enormous amounts of carbon emissions are being released into the atmosphere. Thus, their study suggests that smart transportation is a favorable approach to combating environmental issues. There is a substantial relationship between carbon emissions and smart transportation, indicating that smart transportation impedes carbon emissions, not only in its own development but also in neighboring areas Abbasi et al. (2022a).

2.2 Environment–economic complexity nexus

This strand of the literature concentrates on the nexus between environment and economic complexity across the globe. Former studies (e.g., Can & Gozgor, 2017; Mahmood et al., 2020; Zheng et al., 2021) argue that economic complexity has a remarkable impact on the environment. Precisely, a higher level of economic complexity substantially reduces the detrimental effects of the environment. The reason may be that skills, knowledge, and resource management inject and innovate new skills, technology, or methods into the system, which are then able to incorporate the authentic environmental issues over time. Furthermore, another study, e.g., Doğan et al. (2021), finds that OECD countries have the potential resources to innovate new methods, alternatives, and adaptations related to the environment by spending a large amount of their national income on resource management, skills, and knowledge (economic complexity or research and development). Thus, economic complexity has a substantial effect on the environment. Subsequently, recent studies, e.g., Romero and Gramkow (2021), debate that economic complexity positively affects the environment. This suggests that environmental pollution could be reduced through new skills and technology. Consequently, it assists in the reduction of greenhouse gas emissions. Economic complexity in the economy benefits from reducing carbon emissions, which improves environmental quality (Boleti et al., 2021; Gurdal et al., 2021; Kouton, 2021; Purewal & Haini, 2021).

According to the opposite view put forward by Doğan et al. (2021), environmental quality is worse in middle-income countries than high-income countries due to economic complexity. Another study, e.g., Neagu and Teodoru (2019), analyzed the association between environment and economic complexity in European Union economies and suggested that some economies with a lower level of economic complexity are more vulnerable to environmental damage. Correspondingly, a recent study, e.g., Shahzad et al. (2021), argues that economic complexity deteriorates environmental degradation. Precisely, nonlinear economic complexity can reduce carbon dioxide emissions through new innovation and technology development. In contrast, Adedoyin et al. (2021) found in their studies that economic complexity and environmental degradation have no link at all.

In contrast, Shahzad et al. (2023) also investigated the relationship between biomass energy consumption and economic complexity on the environment. They debate that economic complexity is an unfavorable factor for the environment. The reason may be that a higher level of economic activities and demand for natural resources cause greenhouse emissions in the atmosphere through multiple channels. However, less developed countries might be less affected than developed countries. Saud et al. (2023) developed a long-run association between economic complexity and carbon dioxide emissions by using continuously updated bias-corrected and Dumitrescu and Hurlin causality, including fully modified. Their evidence suggests that economic complexity has a negative long-run relationship with carbon dioxide emissions, which indicates that environmental quality is improved with an increase in economic complexity. More precisely, advancement in technology, skills, and production functions might reduce the carbon emissions in the atmosphere.

Wang et al. (2023) argue that economic complexity is a significant factor in promoting green development. They suggest that economic complexity promotes environmental quality through improving green development efficiency. Precisely, advancement in new methods and technology causes better allocation of resources, which is advantageous for the environment. Balsalobre-Lorente et al. (2022) also debate the nexus between carbon emissions and economic complexity. Their estimation suggests that there is a nonlinear relationship between carbon dioxide emissions and economic complexity, including an N-shaped relationship, which means that an increase in economic complexity increases the value of carbon dioxide emissions in the atmosphere.

Bashir et al. (2022) argue that economic complexity significantly affects environmental quality in the short and long runs. Furthermore, their analysis shows that economic complexity meritoriously reduces environmental degradation. In contrast, other economic activities such as financial development and urbanization have a negative correlation with the environment. Adebayo et al. (2022) analyze the nexus between environment and economic complexity. Their discussion concludes that there is an inverted U-shaped relationship between economic complexity and CO2 emissions. However, economic complexity significantly increases the value of CO2 emissions from the 1st quantile to the 9th quantile. Besides, no significant interconnectedness is found between financial development and carbon dioxide emissions.

2.3 Healthcare expenditures–transportation nexus

The relationship between transportation and healthcare expenditures is documented in previous studies. For instance, Alghnam et al. (2021) quantified the impact of road traffic on healthcare expenditures. Their argument reveals that road traffic positively impacts healthcare expenditures because of injuries on the road. It indicates that the economic burden is

increasing in terms of healthcare expenditures. Subsequently, Nadrian et al. (2020) also evaluated the impact of traffic on health. Their findings exhibit that traffic has negative impacts on health, e.g., psychological, physical, and family mental health. Spending on health-associated variables (as mentioned above) is increased due to traffic jams and congestion. Giallouros et al. (2020) find that active transport is associated with lower cause mortality. However, active travel may increase air pollution (PM2.5), which has negative effects on health. Consequently, healthcare expenditures are substantially increased due to transport activities.

In contrast, Adlakha and Parra (2020) argue that transport has a significant impact on health. Their findings suggest that travel-related activities may affect health, specifically health expenses. Such activities may damage the health, such as depression, psychological issues, and mental illness, which increase the health expenses in order to combat the issues. Bahri et al. (2021) find that transport has a significant influence on healthcare expenses. However, their findings show that transportation (re-routing of electric vehicles related to healthcare) minimizes healthcare expenditures because healthcare workers are better decision-makers. Mowafi et al. (2021) debate that healthcare expenditures are strongly influenced by transportation, particularly road transportation. Their findings suggest that up to 3% of gross domestic product costs are increased due to road transport. Furthermore, household economic burdens are crucially disturbed.

Zaman et al. (2022) argue that healthcare expenses are increased due to logistic-induced carbon emissions. The reason may be that increased logistical operations for carrying the commodities from one location to another release carbon emissions into the atmosphere, which either directly or indirectly affect health. Consequently, healthcare expenditures are increased to overcome the health issues.

2.4 Healthcare expenditures–economic growth nexus

This strand of the literature describes the association between economic growth and healthcare expenditures. Economic growth has a remarkable effect on healthcare expenditures, whereas healthcare expenditures also influence economic growth through multiple economic and health channels. Therefore, several recent studies document the findings and confirm the relationship between healthcare expenditures and economic growth. For instance, Yang et al., (2021a, 2021b) investigated whether economic growth positively affected healthcare expenditures. A rise in economic growth boosts healthcare expenditures. The countries with the highest healthcare expenditures have potential resources for better investment in the public health sector, which could improve the economic climate. Likewise,) quantified the actions related to public health that increase economic growth, excluding the panic of infection COVID-19, prematurely elating the lockdown, and working to remotely alleviate the panic of infection, which strongly influence the rise of economic growth in developed countries (South Korea and the UK). Pu et al. (2021) find that economic growth has a substantial effect on expenditures related to public health in the seven countries. They debated that economic prosperity phases enhanced the health expenditures (e.g., before the 2008 financial crisis), whereas they reduced health expenditures after the financial crisis.

Saha (2022) also investigated the relationship between healthcare expenditure and economic growth. Their investigation reveals that public healthcare expenditure has an impact on economic growth. However, its value is relatively low in domestic private healthcare. In contrast, the effect of healthcare spending on economic growth in the public health domain

is remarkable. The difference between the effects of public and private health expenditure on economic growth is due to the different types of health-oriented infrastructure. Li et al., (2022a, 2022b) investigated the relationship between healthcare expenditures and economic gross domestic product using the ARDL approach. Their results suggest that health expenditures and economic growth have a remarkable impact on carbon dioxide emissions, indicating that an increase in healthcare expenditures and economic activities causes the release of carbon emissions into the atmosphere. Consequently, environmental quality is deteriorating, which affects healthcare expenditures directly or indirectly.

Erdogan and Erdogan (2022) debate that health expenditures drastically impact economic growth. Precisely, out-of-pocket and voluntary health expenditures have asymmetric causal effects from total health expenditures to economic growth but not asymmetric causal effects from compulsory health expenditures. Sengupta (2022) also investigates the relationship between public health expenditure and economic growth and finds that public health expenditures have a negative effect on economic growth in developed economies. However, there is a positive effect on the less developed economies in the long run.

Ibukun and Omisore (2022) suggest that empirical evidence confirms the bidirectional causal relationship between health expenditure and economic growth. Furthermore, it also endorses that carbon dioxide emissions and economic growth have a bidirectional causal relationship. Ideh et al. (2022) investigated the relationship between public health expenditure and economic growth. Their findings reveal that there is a positive correlation between public health expenditures and economic growth in the long run. Vyas et al. (2023) argue that public healthcare expenditures are increased due to poor environmental quality, such as air pollution. Therefore, an increase in health costs spurs pharmaceutical production growth, which leads to economic growth.

Qehaja et al. (2023) also investigate the correlation between health expenditure and economic growth. Their investigation suggests that health expenditures have a remarkable impact on economic growth, especially governmental expenditures on health. Precisely, investment in health-oriented expenditures increases the quantity of health-oriented goods, which leads to economic growth. Aydin and Bozatli (2023) also examine the relationship between health expenditures and economic growth. Their analysis suggests that economic growth has a positive effect on health expenditures. Besides, they incorporate the correlation with carbon dioxide emissions, suggesting that CO2 emissions increase health expenditures in the long run.

2.4.1 Research gap

The aforementioned literature emphasized the conventional association between economic growth, CO2 emissions, and health expenditures. However, this study creates a research gap by adding dissimilar dynamics from different fields, e.g., economic complexity, transport–carbon intensity, and transportation. In contrast, previous studies, e.g., Rokicki et al. (2022), Li et al., (2022a, 2022b), and Balsalobre-Lorente et al. (2022), only focused on greenhouse gas emissions and economic growth instead of specific sectors such as transportation and economic complexity. Furthermore, it also develops a link with transport–carbon intensity and health expenditures, which is not incorporated by the previous studies. Precisely, transport–carbon intensity also deteriorates environmental quality via carbon emissions, air pollution, etc. In such circumstances, this may directly or indirectly affect the health. Besides, this study uses the STIRPAT model with passenger traffic, freight traffic, transport–household expenditures, and economic complexity. This study

also investigates the simultaneous effect of transport–household expenditure and traffic (passenger and freight) on transport–carbon intensity, which is an important determinant for the environment. The reason for this is that a large amount of transportation-related spending raises the transport–carbon intensity through traffic. The previous studies did not analyze the effect of transport–carbon intensity, transportation, and economic complexity on healthcare expenditures, as this study did.

3 Methodology

3.1 Theoretical framework

The current research proposes the conceptual context after reviewing the related literature. Therefore, Fig. 2 illustrates that environment and healthcare expenditures are functions of transportation (e.g., traffic, transport–household expenditures), economic complexity, economic growth, and urban population. More precisely, traffic has a remarkable impact on transport–carbon intensity (TCI). Hussain et al. (2021) argue that traffic causes a rise in carbon emissions. Likewise, transport–household expenditures influence the TCI. The reason may be that higher spending on personal vehicles stimulates traffic on roads, railways, and airways, which releases carbon emissions into the atmosphere. Subsequently, the urban population is also a crucial factor for TCI. It has a positive impact on TCI. Furthermore, a rise in population in urban areas creates demand for transport activities. Consequently, traffic activities are enhanced in the specific areas where urban population growth has expanded. Also, carbon emissions are released from traffic activities. On the contrary, the economic complexity index (ECI) can influence the environment through a wide-ranging perspective of a country's scale, structural, and technological changes (Ahmad et al., 2021b; Wang, 2019). Conversely, ECI enables economies to allocate the given resources, knowledge, and skills, including research and development (R&D) and technological advancement, indicating the upgrade of greener production (Mealy & Teytelboym, 2020). Conversely, poor countries have a shortage of resources to handle efficient knowledge. As a result, economic complexity adversely affects transportation carbon emissions and improves environmental quality.

Additionally, traffic may affect healthcare expenditures because a rise in traffic via road, rail, and air creates several health issues. In order to overcome health issues, spending related to health has increased. Likewise, transport–household expenditures are also an important factor for HEX. It may affect the HEX because individuals' budget constraints are proportional to their income with regard to passenger and
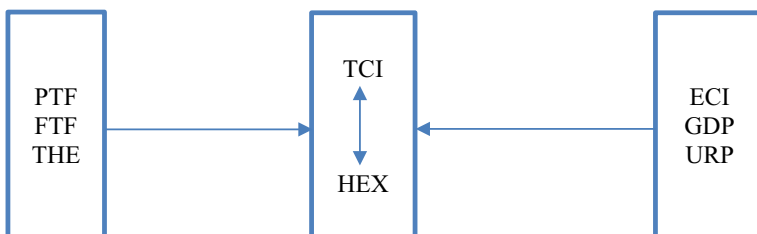

Fig. 2 Theoretical framework

freight movements. Under such circumstances, household expenditures are divided into different groups, e.g., transportation, health, food, and so on. Thus, a specific proportion of income is allocated to overcome the health issues as a healthcare expenditure. In contrast, economic complexity is also a crucial factor for healthcare expenditures. It may have an effect on healthcare expenditures; managing the resources, knowledge, and skills could be effective to reduce the healthcare expenditures through new innovation or methods, which are yielded by the aforementioned variables. Besides, urban population is also an important factor for healthcare expenditures. An increase in the urban population level may positively affect the healthcare expenditures in the specific area. Lastly, gross domestic product may have a dual effect on healthcare expenditures through multiple economic activities.

3.2 Model specification

The current study focuses on the relationship between traffic, transportation-related household expenses, and economic complexity on EF and healthcare expenditures by using panel data from 35 OECD countries. Furthermore, this study employs the STIRPAT model, which insinuates stochastic impacts through regression on important factors such as technology, affluence, and population. A structure for environmental investigation is shaped by integrating the man-made leading dynamics with the basic aspects of environmental challenges, as represented by the IPAT model. This model incorporates factors such as ecological impact (I), population (P), affluence (A), and technology (T) that have a negative or positive impact on the environment (see Ehrlich & Holdren, 1971). The standard IPAT model suggested by ecologists explained mathematical exempla (e.g., $I = PAT$) to develop the correlation with environmental pressure and wealth. Besides, Commoner (1990) proved it in a series of experiments. Dietz and Rosa (1994) anticipated the IPAT equation, which is also known as the STIRPAT model, with the following specifics:

$$I_t = \propto P_t^a A_t^b T_t^c \mu_t \tag{1}$$

Equation (1) reveals that I_t is an indicator of environmental discrepancy (ecological deficit), while the terms 'T,' 'P,' and 'A' show technological advancement, population, and wealth, respectively. Additionally, the exponential powers are expressed in terms of a, b, and c, with indicating the model's coefficient and 't' indicating the time dimension. The epsilon term is displayed by 'μ_t.' Several variables and coefficients are broken down by the STIRPAT model. This model keeps the many linkages between various driving forces while also allowing for non-proportional impacts related to environmental factors. Subsequently, Eq. (1) has been transformed into logarithmic procedure, as shown in Eq. (2):

$$\ln\left(I_{it}\right) = \emptyset_0 + \emptyset_1 \ln\left(P_{it}\right) + \emptyset_2 \ln\left(A_{it}\right) + \emptyset_3 \ln\left(T_{it}\right) + \mu_{it} \tag{2}$$

Environmental impacts (transport–carbon intensity) are denoted by I_{it}, whereas population density (urban population) is represented by P, and economic considerations are denoted by A (affluence or GDP growth). The letter T stands for technological aspects (i.e., healthcare expenditures, economic complexity, traffic, and transport–household expenditures). The STIRPAT model environmental function, given in Eq. (3), has also been modified and expanded as follows:

$$\ln\left(\text{TCI}_{it}\right) = \emptyset_0 + \emptyset_1 \ln\left(\text{HEX}_{it}\right) + \emptyset_2 \ln\left(\text{THE}_{it}\right) + \emptyset_3 \ln\left(\text{PTF}_{it}\right)$$
$$+ \emptyset_4 \ln\left(\text{FTF}_{it}\right) + \emptyset_5 \ln\left(\text{ECI}_{it}\right) + \emptyset_6 \ln\left(\text{GDP}_{it}\right) \qquad (3)$$
$$+ \emptyset_7 \ln\left(\text{URP}_{it}\right) + \emptyset_8 \ln\left(\text{THE} * \text{PRF}_{it}\right) + \mu_{it}$$

In Eq. (3), 'θ' represents the constant term, and the terms $i = 1\dots7$ represent the elasticities of the explanatory variables; the variables lnTCI, lnHEX, lnTHE, lnPTF, lnFTF, lnECI, lnGDP, lnURP, and lnTHE*PRF represent the logarithmic conversions of transportation-carbon intensity, healthcare expenditures, transport–household expenditure. We extend the model for better understanding the public health (especially healthcare expenditures) function, and Eq. (4) is presented as follows:

$$\ln\left(\text{HEX}_{it}\right) = \vartheta_0 + \vartheta_1 \ln\left(\text{TCI}_{it}\right) + \vartheta_2 \ln\left(\text{THE}_{it}\right) + \vartheta_3 \ln\left(\text{PTF}_{it}\right)$$
$$+ \vartheta_4 \ln\left(\text{FTF}_{it}\right) + \vartheta_5 \ln\left(\text{ECI}_{it}\right) + \vartheta_6 \ln\left(\text{GDP}_{it}\right) \qquad (4)$$
$$+ \vartheta_7 \ln\left(\text{URP}_{it}\right) + \vartheta_8 \ln\left(\text{THE} * \text{PRF}_{it}\right) + \omega_{it}$$

Equation (4) shows that healthcare expenditures are a function of lnTCI, lnTHE, lnPTF, lnFTF, lnECI, lnGDP, lnURP, and lnTHE*PRF. The term i refers to cross sections, t denotes the time period, and ω represents the error term.

This research articulates the assumptions aimed over the effects of traffic, transport–household expenditures, and economic complexity on the healthcare expenditure and transport–carbon intensity. For this purpose, the current study examines the following hypotheses:

H1 Is there any evidence that healthcare expenditure has a favorable impact on the transportation-carbon intensity over the long term?

H2 Is there any relationship between the intensity of transport–carbon intensity and health expenditure in the long run?

H3 How do traffic and transportation-related household expenditures effect environmental degradation and health costs in the long run?

H4 What role does economic complexity play in environmental degradation and healthcare expenditures?

3.3 Data

To investigate the effect of traffic, transport–household expenditures, economic complexity, economic growth, and urban population on healthcare expenditure and transport–carbon intensity, we collect the data from 2001 to 2020 for the 35 Organization for Economic Co-operation and Development countries: Austria, Estonia, Belgium, Japan, Hungary, Canada, the Czech Republic, Germany, Australia, Chile, Iceland, Denmark, Italy, Finland, France, Lithuania, Greece, Ireland, Korea, Latvia, Mexico, the Netherlands, Luxembourg, New Zealand, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Sweden, the UK, Turkey, Slovenia, the USA, and Norway.

Operational variables are presented: Transport–carbon intensity (TCI) is measured as a ratio of carbon dioxide per unit of energy released by the transportation sector, including

road, rail, and air; HEX (healthcare expenses) is calculated as a percentage of GDP; ECI (economic complexity index) is measured in index; PCGDP (per capita GDP) is estimated in constant 2010 US dollars; and PTRF (passenger traffic) is measured. These statistics come from three sources, including the World Bank Indicator (WDI), the Organization for Economic Co-operation and Development (OECD), and the Atlas Media Database (AMD). The WDI collects statistics on HEX, PCGDP, and URP, while the OECD collects data on TCI, PTRF, FTRF, and THE. In addition, AMD collects ECI statistics. Data, variables, measurements, and sources can be found in Table 1.

3.4 Methodological framework

This study detects cross-sectional dependence (CD) in the concerned variables. Usually, CD issues arise in the panel data and provide inefficient information. Thus, it is imperative to detect CD in the data in order to avoid the bias. Furthermore, cross-dependence occurs due to international economic integration, financial integration, globalization, and political-economic agreements within the countries. Thus, countries are dependent on each other. Various research studies, e.g., Usman et al. (2020), Khalid et al. (2021), employed different cross-dependence methods (e.g., LM—Breusch & Pagan, 1980; Pesaran scaled LM, 2004; Lagrange multiplier—Baltagi & Moscone, 2010; and CD—Pesaran & Yamagata, 2008).

$$CD = \sqrt{\frac{2T}{N(N-1)}}\left(\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \tilde{\rho}_{ij} \right), \tag{5}$$

Equation (5) represents the pairwise correlation of cross-sectional residuals produced via modified Dickey–Fuller (ADF). As a result, the symbols 'T' and 'N' stand for the dimensions of time and cross section, respectively. Because data are influenced by CD, first-generation stationary tests are useless. It is possible that this could lead to skewed outcomes. Therefore, the current research uses a second-generation test to check the stationarity of the dataset, taking into account the influence of economic complexity in countries that are interdependent. Conscientiously, stationarity assessments such as augmented cross-sectional Dickey Fuller (CADF) and cross-sectional (Im, Pesaran, and Shin) can produce

Table 1 Variables, measure, code, and source

Variable	Measure	Code	Source
Transport–carbon intensity	Ratio of carbon dioxide per unit of energy released by transport sector	TCI	OECD
Healthcare expenditure	% of GDP	HEX	WDI
Economic growth	Per capita Constant	PCGDP	WDI
Economic complexity	Economic complexity Index	ECI	AMD
Passenger's traffic	Passengers*traveled distance	PTRF	OECD
Freight traffic	Weight's freight*traveled distance	FTRF	OECD
Transport–household expenditure	% of transport–household expenditure in terms of US$ in million	THE	OECD
Urbanization population	% of the total population	URP	WDI

consistent outcomes, while the data have CD problems (Hussain et al., 2022; Usman et al., 2021a, 2021b).

Equation (6) expresses the CADF panel stationary test as follows:

$$\Delta CA_{i,t} = \emptyset_i + \emptyset_i Z_{I,t-1} + \emptyset_i \overline{CSA}_{t-1} + \sum_{i=0}^{\rho} \emptyset_{ii} \Delta \overline{CSA}_{t-1}$$
$$+ \sum_{i=0}^{\rho} \emptyset_{ii} \Delta CA_{i,t-1} + \mu_{it} \tag{6}$$

where $(CSA)\_(t-1)$ and $(CSA)\_(t-2)$ denote cross-sectional averages $(t-1)$. Consequently, the CIPS test statistics are as follows:

$$\widetilde{CIPS} = 1/N \sum_{i=1}^{n} CDF_i. \tag{7}$$

In Eq. (7), CDF represents the cross-sectional ADF.

Afterward, the second-generation method is used to deal with the long cointegration between the variables. Conventional techniques, such as the random effects model, fixed effects model, and instrumental variable, do not address CD issues and provide biased outcomes. Moreover, second-generation tests incorporate CD issues while employing the Westerlund long-run integration test proposed by Westerlund to ensure consistent results (2007). A number of subsequent studies (e.g., Usman & Jahanger, 2021; Khalid et al., 2021; Yang et al., 2021b; Usman & Makhdum, 2021; Usman et al., 2020) also support usage of the test.

Equation (8) states the Westerlund cointegration test as follows:

$$\alpha_i(L)\Delta\gamma_{it} = \delta_{1i} + \delta_{2it} + \alpha_i\left(\gamma_{it-1} - \beta_i' x_{it-1} + \lambda_i(L)' v_{it} + \varepsilon_{it}\right), \tag{8}$$

where $\delta_{1i} = \alpha_i(1)\phi_{2i} - \alpha_i\phi_{1i} + \alpha_i\phi_{2i}$, but $\delta_{2i} = -\alpha_i\phi_{2i}$. α_i represents the error correction term. The test statistics is described as

$$G_t = 1/N \sum_{i=1}^{N} \frac{\alpha_i'}{SE(\alpha_i')} \tag{8a}$$

$$G_\alpha = 1/N \sum_{i=1}^{N} \frac{T_i'}{(\alpha_i')1} \tag{8b}$$

$$P_t = \frac{\alpha'}{SE(\alpha')} \tag{8c}$$

$$\alpha' = P_\alpha/T \tag{8d}$$

According to the disequilibrium case, the short-term error correction parameter (α') is defined by the ratio of error to be corrected each year in the short run (P/T). For both long- and short-term runs, the CS-ARDL model is used to estimate how the dependent (TCI and HEX) and explanatory variables (e.g., PTRF and FTRF) relate to each other. Error correction and the cross-sectional mean are included in this model, which takes into account both

the long and short runs. Cross-dependence, non-stationarity, and heterogeneity are a few of the problems it addresses (Ahmad et al., 2021a; Zeqiraj et al., 2020). The suggested model for CS-ARDL is:

$$\Delta \text{TCI}_{i,t} = \vartheta_i + \sum_{j=1}^{\rho} \vartheta_{it} \Delta \text{TCI}_{i,t-1} + \sum_{j=0}^{\rho} \vartheta'_{ij} \text{AV}_{i,t-1} + \sum_{j=0}^{\rho} \vartheta_{it} \overline{Z_{t-j}} + \varepsilon_{it}, \tag{9}$$

$$\Delta \text{HEX}_{i,t} = \vartheta_i + \sum_{j=1}^{\rho} \vartheta_{it} \Delta \text{HEX}_{i,t-1} + \sum_{j=0}^{\rho} \vartheta'_{ij} \text{AV}_{i,t-1} + \sum_{j=0}^{\rho} \vartheta_{it} \overline{Z_{t-j}} + \varepsilon_{it} \tag{10}$$

where AV $(_{i,t-1})$ and (Z_{t-j}) are the independent variables and cross-sectional averages, respectively, in Eqs. (9) and (10).

It was found that the parameters can be heterogeneous in the long run using Pesaran's (2006) common correlated effect mean group (CCEMG) to test for robustness. As a result, the long-term homogeneity restriction imposed by cross-sectional autoregressive distributed lag has been probed. Economies are diverse in terms of economic systems and structures. Despite the fact that CS-ARDL and CCEMG yielded credible results, this research evaluates the relationship between the selected variables and uses the Dumitrescu and Hurlin (D&H, 2012) technique. The average (W) and the standard normal distribution (Z) are supplied as two statistics. The model is referred to as a

$$Z_{i,t} = \alpha_i + \sum_{j=1}^{\rho} \beta_i^j Z_{i,t-1} + \sum_{j=1}^{\rho} \gamma_i^j T_{i,t-j}, \tag{11}$$

where $\beta^j(j)$ and j indicate the autoregressive parameters and lag length, respectively.

4 Empirical results

The outcomes are documented in the logarithms for all the variables in Table 2, which show that economic growth (lnPCGDP) has a higher mean value compared to other variables. On the contrary, the negative logarithm mean value indicates that OECD countries have a negative economic complexity index (lnECI) on average from 2000 to 2020. Besides, the logarithm standard deviation values exhibit that the observations of passenger traffic (lnPTF) are much scattered in comparison with adjacent variables (used

Table 2 Observation, mean, standard deviation range

Variable	Obs.	Mean	S.D.	Min	Max
lnTCI	735	1.344	0.196	0.902	2.167
lnECI	735	−0.120	1.017	−4.605	1.036
lnTHE	735	2.457	0.460	0.000	2.912
lnPCGDP	735	26.555	1.660	19.773	30.696
lnHEX	735	2.098	0.263	1.361	2.886
lnURP	735	2.967	0.919	0.182	4.173
lnPTF	735	4.724	3.775	0.000	21.044
lnFTF	735	2.161	1.587	0.000	8.08

Source Author's calculations

Table 3 Cross-sectional dependence test

Test	Statistic	$\ln TCI_{i,t}$	$\ln HEX_{i,t}$	$\ln THE_{i,t}$	$\ln ECI_{i,t}$	$\ln PCGDP_{i,t}$	$\ln URP_{i,t}$	$\ln PTF_{i,t}$	$\ln FTF_{i,t}$
CD_{BKP}	$\sqrt{\frac{TN(N-1)}{2}}\widehat{\rho}_N$	59.595[a]	51.651[a]	15.873[a]	5.001[a]	48.419[a]	48.497[a]	9.014[a]	0.915[a]

The statistical significance at 1% is denoted by[a]

Source Authors' estimates

Table 4 Homogeneity test

	Model TCI		Model HEX	
Test	Slope coefficient	Prob. value	Slope coefficient	Prob. value
Δ	12.563[a]	0.000	5.562[a]	0.000
$\Delta_{adjusted}$	16.070[a]	0.000	7.642[a]	0.000

The statistical significance at 1% indicate by the term[a]

Source Authors' estimates

in the current model). More interesting findings show that the logarithm observations for transport–carbon intensity (lnTCI) are less scattered than the logarithm healthcare expenditures observations. Overall, the observations are close to the mean values, an indication of consistency in the dataset.

Additionally, we use the CD test to detect the dependency among the selected variables. Thus, the outcomes from CD for each variable (lnTCI, lnHEX, lnTHE, lnECI, lnPCGDP, lnURP, lnPTF, and lnFTF) are reported in Table 3. Therefore, the values ranging from 0.915 to 59.595 supported CD and showed statistical significance at the 1% level of Pesaran's CD test. It argues that the notion of cross-sectional dependence has been rejected in favor of an alternate theory. Because of this, the OECD countries are integrated into an international market. This suggests that even a minor shock to the core variables can have a significant impact on the rest of the world. As a result, countries are dependent on each other cross-sectionally.

After detecting the issue of CD, we test the slope homogeneity by using the Blomquist–Westerlund formula (2013, Economic Letters), which is reported in Table 4. The outcomes reveal that slope coefficients are statistically significant at the 1% level. Moreover, they suggest that the OECD countries have an inconsistent rate of technological advancement, growth, and development level. Thus, it suggests that outcomes endorse the presence of heterogeneousness in the slope's coefficients. Besides, we check the stationarity among the variables by applying the second-generation unit root tests. Therefore, the outcomes from CIPS and CADF tests are reported in Table 5 indicating that some variables $\left(\ln THE_{i,t}, \ln ECI_{i,t}, \ln PCGDP_{i,t}, \ln URP_{i,t}, \ln PTF_{i,t}, \text{ and } \ln FTF_{i,t}\right)$ show the non-stationarity at the level for CADF. However, there are most of the variable's stationarity at $I(1)$ for CIPS. Afterward, Table 6 describes the outcomes from Westerlund cointegration, and the models, e.g., transport–carbon intensity and healthcare expenditures, have long-run cointegration relationships. In addition, EC parameter is $\left(\alpha' = Pa/T\right)$, $-4.899/21 = -0.23$ for TCI model, and $-4.681/21 = -0.22$ for HEX model. This suggests that around 23 and 22% of errors between TCI and HEX and their

Table 5 Unit root tests

Cross-sectional ADF (CADF) test

$\ln \mathrm{TCI}_{i,t}$	$\ln \mathrm{HEX}_{i,t}$	$\ln \mathrm{ECI}_{i,t}$	$\ln \mathrm{PCGDP}_{i,t}$	$\ln \mathrm{PTF}_{i,t}$	$\ln \mathrm{FTF}_{i,t}$	$\ln \mathrm{URP}_{i,t}$
−1.71[a]	−3.48[a]	4.91	−1.72	−0.62	1.51	0.065
$\Delta \ln \mathrm{TCI}_{i,t}$	$\Delta \ln \mathrm{HEX}_{i,t}$	$\Delta \ln \mathrm{ECI}_{i,t}$	$\Delta \ln \mathrm{PCGDP}_{i,t}$	$\Delta \ln \mathrm{PTF}_{i,t}$	$\Delta \ln \mathrm{FTF}_{i,t}$	$\Delta \ln \mathrm{URP}_{i,t}$
−6.40[a]	−6.79[a]	−11.51[a]	−4.65[a]	−8.11[a]	−7.66[a]	−4.61[a]

Cross-sectional IPS (CIPS) test

$\ln \mathrm{TCI}_{i,t}$	$\ln \mathrm{HEX}_{i,t}$	$\ln \mathrm{ECI}_{i,t}$	$\ln PCGDP_{i,t}$	$\ln PTF_{i,t}$	$\ln FTF_{i,t}$	$\ln \mathrm{URP}_{i,t}$
−2.76[c]	−2.16[c]	−3.16	−3.41[c]	−2.59	−2.64	−1.70[c]
$\Delta \ln \mathrm{TCI}_{i,t}$	$\Delta \ln \mathrm{HEX}_{i,t}$	$\Delta \ln \mathrm{ECI}_{i,t}$	$\Delta \ln \mathrm{PCGDP}_{i,t}$	$\Delta \ln \mathrm{PTF}_{i,t}$	$\Delta \ln \mathrm{FTF}_{i,t}$	$\Delta \ln \mathrm{URP}_{i,t}$
−3.67[c]	−3.85[c]	−5.40[c]	−3.65[a]	−4.15[a]	−4.08[c]	−3.25[c]
$\ln \mathrm{TCI}_{i,t}$ is $I(1)$	$\ln \mathrm{HEX}_{i,t}$ is $I(1)$	$\ln \mathrm{ECI}_{i,t}$ is $I(1)$	$\ln \mathrm{PCGDP}_{i,t}$ is $I(1)$	$\ln \mathrm{PTF}_{i,t}$ is $I(1)$	$\ln \mathrm{FTF}_{i,t}$ is $I(1)$	$\ln \mathrm{URP}_{i,t}$ is $I(1)$

By definition: $\mathrm{CIPS} = \dfrac{\sum_{i=1}^{N} t_i(N,T)}{N} = \dfrac{\sum_{i=1}^{N} CADF_i}{N}$

The statistical significance at 1 and 10% is denoted by [a] and [c], respectively

Source Authors' estimates

Table 6 Westerlund Panel Cointegration Test Results

	Model TCI		Model HEX	
	Slope coefficient	Z-value	Slope coefficient	Z-value
Gt	− 2.310[a]	− 3.505	− 3.334[a]	− 10.251
Ga	− 4.475[c]	2.899	− 5.761	1.501
Pt	− 10.051[a]	− 1.496	− 11.149[b]	− 2.600
Pa	− 4.899[a]	− 0.891	− 4.681[c]	− 0.600

The statistical significance at 1, 5 and 10% is reported by the terms [a,] [b,] and [c,] respectively

Source Authors' estimations

determinants would be improved per annum, respectively. Consequently, some instability in the short run is stabled in the long-run model.

4.1 Results on transport–carbon intensity function

After analyzing the cointegration relationship, we concentrate on the relationships between transport–carbon intensity and healthcare expenditures, and their influencers, which are estimated by the cross-sectional autoregressive distributed lag method. The outcomes from CS-ARDL method are provided in Table 7. The results reveal that healthcare expenditure has positive impact on transport–carbon intensity. This suggest that a 1% increase in healthcare expenditures upsurges 24.5% TCI in the long run. Conversely, a 0.3% upsurge in TCI is because of 1% change in lnHEX in the short run. The reason behind that higher spending on healthcare goods effect on transportation, especially road traffic. More analytically, healthcare goods are traded via road, railway, and air routes, and thus, energy consumption from fossil fuels for traffic, e.g., road, railway, and air, is increased in order to meet the traffic needs. Consequently, simultaneously increase demand for traffic vehicles and energy use which released the more carbon dioxide emissions Hussain et al. (2021). Some previous studies, e.g., Yang et al., (2021a, 2021b), Aum et al., (2021a, 2021b) and Pu et al. (2021), also endorse our outcomes, and healthcare expenditures deteriorate the environmental quality. This argument tested hypothesis: Is there any effect of healthcare expenditures on transport–carbon intensity, and concluded transport–carbon intensity is negatively influenced by the healthcare expenditures.

Additionally, transport–household expenditures have a remarkable impact on TCI. Empirical findings reveal that a 54.7% increase in transport–carbon intensity is due to a 1% rise in lnTHE. The short-run outcomes also validated the positive relationship with TCI and LNTHE. It implies that a 1% increase in LNTHE boosts 7.7% in the TCI. The reason is that household expenditures on buying vehicles (e.g., motorcycles, cars, and taxis) increase the demand for energy, which usually comes from the fossil fuels that cause the carbon dioxide emissions in the atmosphere. Thus, an increase in the transportation household expenditures also increases the transport–carbon intensity, which deteriorates the environmental quality and leads to diseases such as physical and mental illnesses. Castellani et al. (2019), Grubb et al. (2020), and Vanova and Wood (2020) also confirm that transportation household expenditures have a substantially negative impact on the environment. However, Hardadi et al. (2021) argue that the distribution of household expenditures intensely influences the environment's quality. By deliberating the consequence of

Table 7 CS-ARDL estimations

Variable	Long run		Variable	Short run	
	Slope coefficient	Standard errors		Slope coefficient	Standard errors
Dependent variable: $\ln TCI_{i,t}$					
$\ln HEX_{i,t}$	0.245	0.175	$\Delta \ln HEX_{i,t}$	0.038	0.096
$\ln THE_{i,t}$	0.547[a]	0.389	$\Delta \ln THE_{i,t}$	0.077[a]	0.081
$\ln PCGDP_{i,t}$	2.556[a]	2.369	$\Delta \ln PCGDP_{i,t}$	0.082[a]	0.027
$\ln ECI_{i,t}$	0.096[b]	0.115	$\Delta \ln ECI_{i,t}$	0.007[b]	0.025
$\ln URP_{i,t}$	0.150[a]	0.262	$\Delta \ln URP_{i,t}$	− 1.299	2.215
$\ln PTF_{i,t}$	0.219[a]	0.023	$\Delta \ln PTF_{i,t}$	0.003[a]	0.004
$\ln FTF_{i,t}$	0.310[a]	0.049	$\Delta \ln FTF_{i,t}$	0.210[a]	0.007
$\ln THE * \ln PTF_{i,t}$	− 0.004[b]	0.005	$\Delta \ln THE * \ln PTF_{i,t}$	0.002[b]	0.002
–	–	–	ECT(−1)	− 0.089[a]	0.047
Dependent variable: $HEX_{i,t}$					
$\ln TCI_{i,t}$	0.048[a]	0.265	$\Delta \ln TCI_{i,t}$	0.159[a]	0.161
$\ln THE_{i,t}$	1.279[a]	1.084	$\Delta \ln THE_{i,t}$	0.125[a]	0.157
$\ln PCGDP_{i,t}$	0.140[a]	0.248	$\Delta \ln PCGDP_{i,t}$	0.082[a]	0.052
$\ln ECI_{i,t}$	0.344[b]	0.543	$\Delta \ln ECI_{i,t}$	0.008[c]	0.054
$\ln URP_{i,t}$	0.841[a]	0.760	$\Delta \ln URP_{i,t}$	0.060[b]	0.766
$\ln PTF_{i,t}$	0.042[a]	0.045	$\Delta \ln PTF_{i,t}$	0.009[b]	0.014
$FTF_{i,t}$	0.485[a]	0.471	$\Delta FTF_{i,t}$	0.001[c]	0.007
$THE * PTF_{i,t}$	0.003[c]	0.001	$\Delta THE * PTF_{i,t}$	0.002[b]	0.002
–			ECT(−1)	− 0.069[a]	0.017

[a], [b,] and [c] show statistical significance at 1%, 5%, and 10%, respectively

Source Authors' estimations

economic growth, the coefficient of lnPCGDP in both the long and short runs is shown to have a positive correlation with transport–carbon intensity. It implies that a 1% increase in lnPCGDP upsurges 255% in TCI in the long run because economic growth in all sectors of the economy requires more resources, which are traded from and to multiple destinations via transportation. Under such circumstances, simultaneously, demand for traffic and energy use rise, which cause the release of carbon dioxide emissions. Several studies, e.g., Hussain et al. (2021), Yang et al., (2021a, 2021b), Cardenete and López-Cabaco (2021), Chu (2021), and Pata (2021), also support our findings that economic growth increases environmental degradation. However, some studies, e.g., Churchill et al. (2021) and Neagu and Teodoru (2019), argue that economic growth initially decreases environmental quality and later increases it through adaptation and mitigation approaches.

We further emphasize the impact of economic complexity on environmental quality. Thus, the outcomes reveal that the economic complexity index (ECI)'s coefficient has an incredible effect on transport–carbon intensity; this indicates that a 9.6% increase in TCI is due to a 1% change in the ECI in the long run. The outcomes are reported in the short run, which also validates that there is a positive association with TCI, which implies that a 1% increase in LECI upsurges 8.2% in the TCI. This suggests OECD countries can manage their skills, knowledge, and resources in order to stabilize the economic system. Under

such circumstances, production activities produce a higher level of carbon dioxide emissions via transportation, which is not environmentally friendly. The outcomes line up with the strands of Ahmad et al. (2020) and Shahzad et al. (2020). In contrast, Dogan et al. (2020) argue that economic complexity has a positive effect on environmental quality, an indication of a reduction in environmental deterioration.

By pondering the outcome of traffic, the coefficient of passenger traffic (lnPTF) has a positive impact on transport–carbon intensity (lnTCI), which implies that a 1% change in lnPTF increases 21.9% lnTCI in the long run. The outcomes from the short run also validated that passenger traffic has a positive association with transport–carbon intensity, which implies that a 0.3% increase in lnTCI is due to a 1% increase in lnPTF. The reason behind those passengers is that they use fossil fuel vehicles for travel in order to meet the needs of tourism, business, health, education, trade, and other daily activities. As a result, traffic levels are enhanced on the roads, railways, and air routes that release carbon dioxide emissions into the atmosphere. Thus, environmental quality is deteriorating in the sample countries. On the contrary, the coefficient of freight traffic (lnFTF) also has a positive impact on lnTCI. This implies that a 1% change in lnFTF enhances 31% of transport–carbon intensity in the long run, while short-run outcomes reveal that a 21% increase in lnTCI is due to a 1% change in lnFTF. Because freights are also traded via road, railway, and air routes from and to multiple origins and destinations due to several factors such as national and international trade, urbanization, and industrialization (Hussain et al., 2020; Yang et al., 2021a, 2021b), other studies, e.g., Hussain et al. (2021), Churchill et al. (2021), and Hussain et al. (2020), also debate that traffic substantially increases emissions, an indication of higher transport–carbon intensity that deteriorates environmental quality. Besides, the urban population also has a significant impact on transport–carbon intensity in the long and short runs. The outcomes show that the coefficient of lnURP has a positive impact on lnTCI in the long run, while transport–carbon intensity is negatively influenced in the short run, which implies that a 15% increase in lnTCI is due to a 1% change in lnURP and a 129% decrease in lnTCI is due to a 1% increase in lnURP, which is insignificant.

4.2 Results on healthcare expenditure function

We document the findings on estimates of healthcare expenditure and its determinants in Table 7. The results exhibit that transport–carbon intensity has a positive effect on HEX. The variable, e.g., lnTCI, increases healthcare expenditures by 4.8% in the long run. In contrast, a 15.9% increase in healthcare expenditure is due to a 1% change in transport–carbon intensity in the short run. The positive effect of transportation-related carbon intensity on healthcare expenditure is reasonable because OECD countries are improving their transportation systems, which produce desirable and undesirable outputs (e.g., air pollution, PM2.5, carbon dioxide emissions) that directly and indirectly affect public health in the form of diseases (Khan et al., 2020; Ullah et al., 2019). These findings are in line with theoretical expectations that environmental degradation is not favorable to public health.

The results further portray interesting findings: The coefficient of transport–household expenditures has a positive effect on healthcare expenses. A 1% rise in LNTHE enhances 127.9% of healthcare expenditures over the long term. Conversely, the outcomes in the short run also confirm that household transportation expenditures have a positive influence on healthcare expenditures. The reason behind this is that spending on transport vehicles increases transport–household expenditures, by which individuals travel more; thus, an increase in travel may affect physical and mental health. Under such circumstances,

diseases such as depression and anxiety are activated in the human body. In order to tackle the health issues, household expenditures are increased (Baltagi & Moscone, 2010; Ben Jebli, 2016; Cervantes et al., 2020). Economic growth also has an optimistic effect on healthcare expenditures, which refers to a 14% increase in lnHEX due to a 1% change in lnPCGDP. Conversely, outcomes calculated in the short run also endorse that there is a positive link concerning lnHEX and lnPCGDP and report an increase of approximately 8% due to a 1% increase in economic growth. The reason is that those countries can re-allocate their resources with more concern for public health over a longer period of time in comparison with the short term. Interestingly, economic complexity (ECI) also has a positive impact on healthcare expenditures.

This suggests that managing the resources, skills, and knowledge by the countries enhances the healthcare expenditures in order to maintain the public health standards. Furthermore, it provides new methods or innovations and consumption patterns for health-related activities as well. Thus, the coefficient of lnECI indicates that a 34 and 0.08% increase in healthcare expenditures are due to a 1% change in lnECI in the long and short runs, respectively. The reason behind that is that those countries cannot produce the outcomes from managing or utilizing the resources, skills, and knowledge within a short period of time; however, in the long run, the effect could be positive on public health. More interestingly, the coefficient of passenger traffic has increased along with healthcare expenditures. This indicates a 4.2% increase in healthcare expenditures is due to a 1% change in passenger traffic in the long run, whereas a 1% increase in lnPTF upsurges 0.09% in the short run. Because long-distance travel via road, railway, and air routes is effective for diseases such as depression, anxiety, and fatigue, which appear in the long run and require a large amount to be recovered, likewise, freight's traffic has a positive impact on healthcare expenditures. Both have almost similar mechanisms for healthcare expenditures.

4.2.1 Robustness check

To check the endogeneity, we employ a common correlated effects mean group (CCEMG) model that refers to common parameters in the countries. Thus, CCEMG can eliminate the possible cross-dependence among the variables that are used in the current models. Furthermore, panel countries have different slope coefficients, which may be accounted for by merely taking the average of the coefficients for each country. As a substitute for CCEMG, Eberhardt and Teal (2010) suggested using an augmented mean group (AMG). Group-specific effects are captured, and the group average is taken as a standard measure. Therefore, the outcomes from CCEMG and AMG are reported in Table 8, which seemed to show consistency among the variables. Besides, the outcomes from the Granger causality test are provided in Table 9. Results reveal that any policy shock in transport–carbon intensity can affect healthcare expenditures. This suggests that mitigation of environmental issues may have a positive effect on healthcare expenditures. More precisely, a clean environment can also enhance the healthcare expenditures in the sample countries. There is a unilateral relationship between TCI and economic growth, which indicates that any policy shock in TCI will not affect economic growth. Interestingly, results further suggest that traffic and healthcare expenditures have a bi-causal relationship, which means any policy shock in traffic may affect healthcare expenditures. It indicates that lower traffic activities may reduce the health issues and also decrease healthcare expenditures related to medicine or maintaining health.

Table 8 CCEMG and AMG

| | Dependent variable: $TCI_{i,t} TCI_{i,t}$ | | | |
| | CCEMG | | AMG | |
Variable	Slope coefficient	Standard errors	Slope coefficient	Standard errors
$HEX_{i,t}$	0.017[a]	0.194	0.018[a]	0.029
$THE_{i,t}$	0.056[a]	0.847	0.031[b]	0.175
$PCGDP_{i,t}$	0.064[a]	0.074	0.132[a]	0.033
$ECI_{i,t}$	0.145[b]	0.054	0.014[c]	0.019
$URP_{i,t}$	1.973[b]	2.221	−1.392	1.736
$PTF_{i,t}$	0.035[b]	0.278	0.038[c]	0.038
$FTF_{i,t}$	0.021[b]	0.028	−0.005	0.007
$THE * PTF_{i,t}$	−0.005[a]	0.020	−0.002[a]	0.003
Country Trend	−0.012	0.037	−0.005	0.005
Constant	0.4498	0.396	0.938[a]	0.228
Dependent variable: $HEX_{i,t}$				
$TCI_{i,t}$	0.011[b]	0.302	0.066[a]	0.185
$THE_{i,t}$	−0.421[a]	0.294	0.193[c]	0.278
$PCGDP_{i,t}$	0.017[a]	0.109	0.082[b]	0.074
$ECI_{i,t}$	0.026[a]	0.044	0.007[b]	0.039
$URP_{i,t}$	0.083[a]	0.482	0.736[a]	1.207
$PTF_{i,t}$	0.105[b]	0.090	0.129[b]	0.117
$FTF_{i,t}$	0.004[a]	0.012	0.016[c]	0.025
$THE * PTF_{i,t}$	0.007[a]	0.006	0.018[a]	0.008
Country Trend	0.033[a]	0.023	0.022[a]	0.043
Constant	0.453[a]	0.254	0.543[a]	0.321

The statistical significance at 1, 5, and 10% is reported by the terms [a], [b,] and [c,] respectively

Source Author's estimations

5 Conclusion

This article analyzes the influence of transportation and economic complexity on environmental and healthcare expenditures in OECD countries. To do so, suitable variables and panel data periods from 2001 to 2020 are used under the framework of the STIRPAT model (stochastic influences by regression on the population, affluence, and technology). Furthermore, an advanced econometric method is also employed to estimate the relationship. Therefore, this analysis emphasizes the transport–carbon intensity and healthcare expenditure functions and their determinants. Thus, findings reveal that healthcare expenditures increase the transport–carbon intensity by 24.5% and 3.8% in the long run and short run, respectively. On the contrary, transport–carbon intensity causes the rise in healthcare expenditures that is narrated by 4.8 and 15.9% in the long run and short run, respectively. More precisely, spending on health-oriented commodities by the individuals stimulates the transportation vehicles; these vehicles consume energy via modes of transport such as motorbikes, cars, and buses; in such circumstances, CO_2 emissions are released by such vehicles. Consequently, transport–carbon intensity is increased during the specific time period. Findings further suggest that transport–carbon intensity and healthcare

Table 9 Dumitrescu–Hurlin causality test results

Dependent variable: $TCI_{i,t}$

Causality	$W_{N,T}^{HNC}$	$\tilde{Z}_N^{HNC}$	p value	Remarks
$HEX_{i,t} \rightarrow TCI_{i,t}$	0.6356	1.6561	0.009	Homogeneous Bi-causal Relationship between Transport–carbon intensity and Healthcare Expenditures
$TCI_{i,t} \rightarrow HEX_{i,t}$	3.4755	7.7929	0.000	
$THE_{i,t} \rightarrow TCI_{i,t}$	1.321	1.983	0.000	Homogeneous Bi-causal Relationship between Transport–carbon intensity and Transport–household Expenditures
$TCI_{i,t} \rightarrow THE_{i,t}$	1.432	1.735	0.002	
$ECI_{i,t} \rightarrow TCI_{i,t}$	1.9391	2.6808	0.007	Homogeneous Bi-causal Relationship between Transport–carbon intensity and Economic Complexity Index
$TCI_{i,t} \rightarrow ECI_{i,t}$	0.9823	0.5024	0.615	
$PCGDP_{i,t} \rightarrow TCI_{i,t}$	1.6181	1.6130	0.106	Homogeneous Uni-causal Relationship between Transport–carbon intensity and Economic Growth
$TCI_{i,t} \rightarrow PCGDP_{i,t}$	1.432	1.234	0.001	
$PTF_{i,t} \rightarrow TCI_{i,t}$	1.9202	2.6181	0.008	Homogeneous Uni-causal Relationship between Transport–carbon intensity and Passenger Traffic
$TCI_{i,t} \rightarrow PTF_{i,t}$	1.5788	1.4820	0.138	
$FTF_{i,t} \rightarrow TCI_{i,t}$	4.2375	10.3281	0.000	Homogeneous Uni-causal Relationship between Transport–carbon intensity and Freight Traffic
$TCI_{i,t} \rightarrow FTF_{i,t}$	1.3455	0.7059	0.480	
Dependent variable: $HEX_{i,t}$				
$ECI_{i,t} \rightarrow HEX_{i,t}$	3.8818	9.1445	0.000	Homogeneous Bi-causal Relationship between Healthcare Expenditures and Economic Complexity
$HEX_{i,t} \rightarrow ECI_{i,t}$	1.9414	2.6885	0.007	
$PCGDP_{i,t} \rightarrow HEX_{i,t}$	1.3243	0.6354	0.525	Homogeneous Bi-causal Relationship between Healthcare Expenditure and Economic Growth
$HEX_{i,t} \rightarrow PCGDP_{i,t}$	1.4321	0.2345	0.324	
$PTF_{i,t} \rightarrow HEX_{i,t}$	2.6576	5.0713	0.000	Homogeneous Bi-causal Relationship between Healthcare Expenditures and Passenger Traffic
$HEX_{i,t} \rightarrow PTF_{i,t}$	1.4888	1.1827	0.236	
$FTF_{i,t} \rightarrow HEX_{i,t}$	2.9072	5.9021	0.000	Homogeneous Bi-causal Relationship between Healthcare Expenditures and Freight Traffic
$HEX_{i,t} \rightarrow FTF_{i,t}$	1.1414	0.0270	0.978	

Source Authors' estimates

expenditures have a bi-causal relationship, indicating that transport–carbon intensity also increases healthcare expenditure in terms of transport-oriented diseases such as depression and anxiety.

Furthermore, continued economic growth will degrade environmental quality by increasing the carbon intensity of transportation. Findings document that a 255% increase in transport–carbon intensity is due to a 1% change in economic growth. This also has a positive impact on healthcare expenditures, as reported by 127.9% in the long run. It indicates that enormous economic activities drastically increase the transport–carbon intensity and healthcare expenditures in the countries. Precisely, an increase in investment projects required transport vehicles and energy at the same time that carbon emissions were released. As a result of the polluted environment's direct impact on health, healthcare expenditures have skyrocketed. More interestingly, the economic complexity index also significantly contributes to the environment and public health; thus, the economic complexity index increases transport–carbon intensity by 9.6% and augments healthcare expenditures by approximately 34.4%. Precisely, the management of the resources, skills, and knowledge causes the restriction of transportation and the economic network in the countries. Initially, it has a negative effect on the environment due to the greater demand for resources, but an advancement of new methods, techniques, or technology helps overcome the environmental and healthcare expenditures. Consequently, transport–carbon intensity and healthcare expenditures can have a tendency to increase over the time period. Results further demonstrate that passenger and freight traffic have a positive and significant impact on the environment and public health. Specifically, transport–carbon intensity and healthcare expenditures are enhanced due to the higher traffic levels in OECD countries. Although they have better transportation and health systems, the reason behind this is that a large number of travelers use fossil fuel-powered modes of transportation for short and long routes, which pollute the environment through carbon emissions and air pollution. Polluted environments adulterate the health, which is the determinant of healthcare expenditures.

6 Policy implications

This research recommends some policy implications based on empirical findings, which are the following: (1) Findings suggest that countries should regulate economic growth to reduce transport–carbon intensity by 246% on average, which deteriorates environmental quality. (2) Continued economic growth is likely to degrade the environment, which indirectly enhances healthcare expenditures. Under such circumstances, policymakers must control the spending on healthcare expenditures by 20% on average, because higher demand for healthcare goods and services stimulates the transport activities that cause carbon emissions. (3) Likewise, passenger and freight traffic also should be reduced by around 109 percent because enormous vehicles are being operated on the road, railway, and air routes. Transport experts should manage transport activities, especially on roads, because gigantic passengers cause congestion that causes transport intensity. (4) Transporters or policymakers should moderate the freight traffic by 69% to reduce the transport–carbon intensity. (5) On the contrary, transport experts should reduce the transport–carbon intensity by 95% in order to reduce healthcare expenditures. (6) Public health experts should concentrate on health activities, specifically expenditure-oriented health. The reason behind that higher healthcare expenditures can

generate economic growth is that they are also transported via transport modes. Thus, public health experts must design an expenditure pattern in order to maintain healthcare expenditures at 27%. (7) Transport experts and policymakers should reduce passenger and freight traffic by 58 and 51%, respectively, to control healthcare expenditures. (8) In engineering settings, this study also recommends engineers concern over environment- and health-oriented products. Engineers should design health- and environment-oriented transport vehicles that simultaneously tackle the carbon emissions and diseases instigated by travel activities. Likewise, transport companies also should produce green vehicles, such as electric cars, buses, and trains, at minimum cost to combat carbon emission issues. Also, they should use alternative energy to mitigate pollution. (9) Furthermore, pharmaceutical companies can get advantages from the current model regarding the production of transport-oriented medicines. Indeed, medicines are used during travel activities. (10) Environmental, transport, and health-oriented companies can simultaneously accelerate the mutual production concern over environmental and health issues. Furthermore, the current model suggests that companies form a cartel or joint venture to produce mutual environmental, transportation, and health-related commodities.

This research describes some limitations: Transport–carbon intensity, healthcare expenditures as a percentage of gross domestic product, economic growth in GDP per capita, economic complexity index, passenger and freight travel via distance in kilometers, and transport-household expenditures are employed in the analysis. More precisely, transport–carbon intensity is used for analysis, and the reason behind that ratio of CO_2 emissions per unit of energy released by transport directly associates with a combination of energy use and vehicles (which are transported for commodities movements). Healthcare expenditures in terms of percentage of GDP are also assumed in this study; the reason is that expenditures are components of economic GDP and are made on health-oriented commodities. Healthcare expenditure also refers to quality of life, making it important for inclusion. Furthermore, the economic complexity index refers to research and development and innovative goods. Thus, this factor is included in the current model. Transport-household expenditure indirectly contributes to the value of CO_2 emissions through dissimilar household-related activities. Likewise, passenger and freight traffic also assumed that the number of passengers and freight radically consume energy via the use of vehicles for travel activities.

Thus, future research can be conducted by using other related variables such as environment and transport footprint, energy consumption, pharmaceutical expenditures, health expenditure per capita, ratio of health expenditure to GDP, and geographical area, e.g., One-Belt One-Road (OBOR) countries, Brazil, Russia, India, China, and South Africa (BRICS), emerging economies, because they are being progressed and are populous, advanced technologists, emerging markets, and have rapid economic growth. Furthermore, out-of-pocket expenses can also be investigated; the reason may be that the individual's income fluctuates with respect to time and may affect the individual's budget, particularly for health-oriented products. Consequently, healthcare expenditures are drastically affected. Another set of environmental factors, such as air pollution and greenhouse gases, directly or indirectly affects health. Thus, it is important to consider it for investigation. The role of technology is also imperative for both transport- and health-oriented products. Precisely, advancement in technology provides new techniques to tackle environmental and health issues. Thus, it can also be analyzed for future research.

Declarations

Conflict of interest The authors declare that they have no conflict of interest.

References

Abbasi, S., & Choukolaei, H. A. (2023). A systematic review of green supply chain network design literature focusing on carbon policy. *Decision Analytics Journal*, 100189.

Abbasi, S., & Erdebilli, B. (2023). Green closed-loop supply chain networks' response to various carbon policies during COVID-19. *Sustainability, 15*(4), 3677.

Abbasi, S., Daneshmand-Mehr, M., & Ghane Kanafi, A. (2022a). Designing sustainable recovery network of end-of-life product during the COVID-19 pandemic: A real and applied case study. *Discrete Dynamics in Nature and Society*.

Abbasi, S., Daneshmand-Mehr, M., & GhaneKanafi, A. (2023a). Green closed-loop supply chain network design during the coronavirus (COVID-19) pandemic: A case study in the Iranian Automotive Industry. *Environmental Modeling & Assessment, 28*(1), 69–103.

Abbasi, S., Daneshmand-Mehr, M., & Ghane, K. (2023b). Designing a tri-objective, sustainable, closed-loop, and multi-echelon supply chain during the COVID-19 and lockdowns. Foundations of Computing and Decision Sciences, *48*.

Abbasi, S., Daneshmand-Mehr, M., & Kanafi, A. G. (2021). The sustainable supply chain of CO2 emissions during the coronavirus disease (COVID-19) pandemic. *Journal of Industrial Engineering International, 17*(4), 83–108.

Abbasi, S., Khalili, H. A., Daneshmand-Mehr, M., & Hajiaghaei-Keshteli, M. (2022b). Performance measurement of the sustainable supply chain during the COVID-19 pandemic: A real-life case study. *Foundations of Computing and Decision Sciences, 47*(4), 327–358.

Adebayo, T. S., Rjoub, H., Akadiri, S. S., Oladipupo, S. D., Sharif, A., & Adeshola, I. (2022). The role of economic complexity in the environmental Kuznets curve of MINT economies: Evidence from method of moments quantile regression. *Environmental Science and Pollution Research, 29*(16), 24248–24260.

Adedoyin, F. F., Alola, A. A., & Bekun, F. V. (2021). The alternative energy utilization and common regional trade outlook in EU-27: Evidence from common correlated effects. *Renewable and Sustainable Energy Reviews, 145*, 111092.

Adlakha, D., & Parra, D. C. (2020). Mind the gap: Gender differences in walkability, transportation and physical activity in urban India. *Journal of Transport & Health, 18*, 100875. https://doi.org/10.1016/j.jth.2020.100875

Ahmad, M., Jiang, P., Majeed, A., Umar, M., Khan, Z., & Muhammad, S. (2020). The dynamic impact of natural resources, technological innovations and economic growth on ecological footprint: an advanced panel data estimation. *Resources Policy, 69*, 101817.

Ahmad, M., Rehman, A., Shah, S. A. A., Solangi, Y. A., Chandio, A. A., & Jabeen, G. (2021a). Stylized heterogeneous dynamic links among healthcare expenditures, land urbanization, and CO2 emissions across economic development levels. *Science of the Total Environment, 753*, 142228.

Ahmad, M., Zahoor, A., Abdul, M., & Bo, H. (2021b). An environmental impact assessment of economic complexity and energy consumption: Does institutional quality make a difference? *Environmental Impact Assessment Review, 89*, 106603.

Alghnam, S., Alkelya, M., Aldahnim, M., Aljerian, N., Albabtain, I., Alsayari, A., Da'ar, O. B., Alsheikh, K., & Alghamdi, A. (2021). Healthcare costs of road injuries in Saudi Arabia: A quantile regression analysis. *Accident Analysis & Prevention, 159*, 106266. https://doi.org/10.1016/j.aap.2021.106266

Aum, S., Lee, S. Y. T., & Shin, Y. (2021a). Covid-19 doesn't need lockdowns to destroy jobs: The effect of local outbreaks in Korea. *Labour Economics, 70*, 101993.

Aum, S., Lee, S. Y. T., & Shin, Y. (2021b). Inequality of fear and self-quarantine: Is there a trade-off between GDP and public health? *Journal of Public Economics, 194*, 104354. https://doi.org/10.1016/j.jpubeco.202

Aydin, M., & Bozatli, O. (2023). The impacts of the refugee population, renewable energy consumption, carbon emissions, and economic growth on health expenditure in Turkey: new evidence from Fourier-based analyses. *Environmental Science and Pollution Research*, 1–13.

Bahri, O., Talbi, E. G., & Amodeo, L. (2021). Use of electric vehicles in home-health care routing problems: Analysis of a multi-objective approach under uncertainty. *IFAC-PapersOnLine, 54*(2), 127–132.

Balsalobre-Lorente, D., Ibáñez-Luzón, L., Usman, M., & Shahbaz, M. (2022). The environmental Kuznets curve, based on the economic complexity, and the pollution haven hypothesis in PIIGS countries. *Renewable Energy, 185*, 1441–1455.

Baltagi, B. H., & Moscone, F. (2010). Health care expenditure and income in the OECD reconsidered: Evidence from panel data. *Economic Modelling, 27*(4), 804–811. https://doi.org/10.1016/j.econmod.2009.12.001

Bashir, M. F., Benjiang, M. A., Hussain, H. I., Shahbaz, M., Koca, K., & Shahzadi, I. (2022). Evaluating environmental commitments to COP21 and the role of economic complexity, renewable energy, financial development, urbanization, and energy innovation: Empirical evidence from the RCEP countries. *Renewable Energy, 184*, 541–550.

Ben Jebli, M. (2016). On the causal links between health indicator, output, combustible renewables and waste consumption, rail transport, and CO2 emissions: the case of Tunisia. *Environmental Science and Pollution Research, 23*(16), 16699–16715. https://doi.org/10.1007/s11356-016-6850-7

Boleti, E., Garas, A., Kyriakou, A., & Lapatinas, A. (2021). Economic complexity and environmental performance: Evidence from a world sample. *Environmental Modeling & Assessment, 26*(3), 251–270.

Breusch, T. S., & Pagan, A. R. (1980). The Lagrange multiplier test and its applications to model specification in econometrics. *The Review of Economic Studies, 47*(1), 239–253. https://doi.org/10.2307/2297111

Can, M., & Gozgor, G. (2017). The impact of economic complexity on carbon emissions: Evidence from France. *Environmental Science and Pollution Research, 24*(19), 16364–16370.

Cardenete, M. A., & López-Cabaco, R. (2021). Economic and environmental impact of the new Mediterranean Rail Corridor in Andalusia: A dynamic CGE approach. *Transport Policy, 102*, 25–34.

Castellani, V., Beylot, A., & Sala, S. (2019). Environmental impacts of household consumption in Europe: Comparing process-based LCA and environmentally extended input-output analysis. *Journal of Cleaner Production, 240*, 117966.

Cervantes, P. A. M., López, N. R., & Rambaud, S. C. (2020). The relative importance of globalization and public expenditure on life expectancy in Europe: an approach based on MARS methodology. *International Journal of Environmental Research and Public Health, 17*(22), 8614. https://doi.org/10.3390/ijerph17228614

Choudhari, T., Budhkar, A., & Maji, A. (2022). Modeling overtaking distance and time along two-lane undivided rural highways in mixed traffic condition. *Transportation Letters, 14*(2), 75–83.

Chu, L. K. (2021). Economic structure and environmental Kuznets curve hypothesis: New evidence from economic complexity. *Applied Economics Letters, 28*(7), 612–616.

Churchill, S. A., Inekwe, J., Ivanovski, K., & Smyth, R. (2021). Transport infrastructure and CO2 emissions in the OECD over the long run. *Transportation Research Part D: Transport and Environment, 95*, 102857.

Commoner, B. (1990). *Making peace with the planet*. Pantheon Books.

de Albornoz, V. A. C., Millán, J. M., Galera, A. L., & Medina, B. M. (2022). Road speed limit matters—are politicians doing the right thing? *Socio-Economic Planning Sciences, 79*, 101106.

Dietz, T., & Rosa, E. A. (1994). Rethinking the environmental impacts of population, affluence and technology. *Human Ecology Review, 1*(2), 277–300. https://www.jstor.org/stable/24706840

Dingil, A. E., & Esztergár-Kiss, D. (2021). The influence of the Covid-19 pandemic on mobility patterns: The first Wave's results. *Transportation Letters, 13*(5–6), 434–446.

Dogan, E., Ulucak, R., Kocak, E., & Isik, C. (2020). The use of ecological footprint in estimating the environmental Kuznets curve hypothesis for BRICST by considering cross-section dependence and heterogeneity. *Science of The Total Environment, 723*, 138063. https://doi.org/10.1016/j.egyr.2020.06.004

Doğan, B., Driha, O. M., Balsalobre Lorente, D., & Shahzad, U. (2021). The mitigating effects of economic complexity and renewable energy on carbon emissions in developed countries. *Sustainable Development, 29*(1), 1–12.

Dumitrescu, E. I., & Hurlin, C. (2012). Testing for Granger non-causality in heterogeneous panels. *Economic Modelling, 29*(4), 1450–1460.

Eberhardt, M., & Teal, F. (2010). Productivity analysis in global manufacturing production.

Ehrlich, P. R., & Holdren, J. P. (1971). Impact of population growth. *Science*, *171*(3977), 1212–1217. https://www.jstor.org/stable/1731166.

Erdogan, S., & Erdogan, E. S. (2022). Analyzing the asymmetric effect of disaggregated health expenditures on economic growth. *Quality & Quantity*, 1–14.

Geue, C., Briggs, A., Lewsey, J., & Lorgelly, P. (2014). Population ageing and healthcare expenditure projections: New evidence from a time to death approach. *The European Journal of Health Economics,* *15*(8), 885–896. https://doi.org/10.1007/s10198-013-0543-7

Giallouros, G., Kouis, P., Papatheodorou, S. I., Woodcock, J., & Tainio, M. (2020). The long-term impact of restricting cycling and walking during high air pollution days on all-cause mortality: Health impact assessment study. *Environment International, 140*, 105679.

Grubb, M., Crawford-Brown, D., Neuhoff, K., Schanes, K., Hawkins, S., & Poncia, A. (2020). Consumption-oriented policy instruments for fostering greenhousegas mitigation. *Climate Policy, 20*(Supp 1), S58–S73.

Gurdal, T., Aydin, M., & Inal, V. (2021). The relationship between tax revenue, government expenditure, and economic growth in G7 countries: New evidence from time and frequency domain approaches. *Economic Change and Restructuring, 54*(2), 305–337.

Hardadi, G., Buchholz, A., & Pauliuk, S. (2021). Implications of the distribution of German household environmental footprints across income groups for integrating environmental and social policy design. *Journal of Industrial Ecology, 25*(1), 95–113.

Heidari, E., Bikdeli, S., & Mansouri Daneshvar, M. R. (2022). A dynamic model for CO_2 emissions induced by urban transportation during 2005–2030, a case study of Mashhad, Iran. *Environment, Development and Sustainability*, 1–20.

Herberholz, C., & Phuntsho, S. (2021). Medical, transportation and spiritual out-of-pocket health expenditure on outpatient and inpatient visits in Bhutan. *Social Science & Medicine, 273*, 113780.

Hussain, Z., Yousaf, M., & Miao, C. (2020). Investigating the simultaneous impacts on transport infrastructure: Evidence from one-belt one-road countries. *International Journal of Transport Economics, 47*(4), 401–417.

Hussain, Z., Miao, C., Zhang, W., Khan, M. K., & Xia, Z. (2021). Assessing the role of environmental expenditures and green transport in emissions released by transport: An application of ARDL approach. *Frontiers in Environmental Science*, *488*. https://doi.org/10.3389/fenvs.2021.769608

Hussain, Z., Kaleem Khan, M., & Xia, Z. (2022). Investigating the role of green transport, environmental taxes and expenditures in mitigating the transport CO_2 emissions. *Transportation Letters*, 1–11.

Ibukun, C. O., & Omisore, W. M. (2022). Air pollution, health expenditure and economic growth in MINT countries: a trivariate causality test. *Journal of Economic and Administrative Sciences*, (ahead-of-print).

Ideh, A. N., Nenbee, S. G., & Vite, B. N. (2022). Public Healthcare expenditure, population growth and economic development in Nigeria. *International Journal of Public Health, Pharmacy and Pharmacology, 7*(3), 1–13.

Isphording, I. E., & Pestel, N. (2021). Pandemic meets pollution: Poor air quality increases deaths by COVID-19. *Journal of Environmental Economics and Management, 108*, 102448.

Jiang, S. Y. (2022). Transition and innovation ecosystem–investigating technologies, focal actors, and institution in eHealth innovations. *Technological Forecasting and Social Change, 175*, 121369.

Jin, C., Liu, Y., Li, Z., Gong, R., Huang, M., & Wen, J. (2022). Ecological consequences of China's regional development strategy: evidence from water ecological footprint in Yangtze River Economic Belt. *Environment, Development and Sustainability*, 1–16.

Khalid, K., Usman, M., & Mehdi, M. A. (2021). The determinants of environmental quality in the SAARC region: A spatial heterogeneous panel data approach. *Environmental Science and Pollution Research, 28*(6), 6422–6436. https://doi.org/10.1007/s11356-020-10896-9

Khan, H., Weili, L., & Khan, I. (2022). Environmental innovation, trade openness and quality institutions: An integrated investigation about environmental sustainability. *Environment, Development and Sustainability, 24*(3), 3832–3862.

Khan, Z., Ali, S., Umar, M., Kirikkaleli, D., & Jiao, Z. (2020). Consumption-based carbon emissions and international trade in G7 countries: The role of environmental innovation and renewable energy. *Science of the Total Environment*, 138945

Konc, T., Savin, I., & van den Bergh, J. C. (2021). The social multiplier of environmental policy: Application to carbon taxation. *Journal of Environmental Economics and Management, 105*, 102396.

Kouton, J. (2021). The impact of renewable energy consumption on inclusive growth: panel data analysis in 44 African countries. *Economic Change & Restructuring*, *54*(1).

Kumar, S., & Dua, P. (2022). Environmental management practices and financial performance: Evidence from large listed Indian enterprises. *Journal of Environmental Planning and Management, 65*(1), 37–61.

Li, F., Chang, T., Wang, M. C., & Zhou, J. (2022a). The relationship between health expenditure, CO2 emissions, and economic growth in the BRICS countries—based on the Fourier ARDL model. *Environmental Science and Pollution Research*, 1–20.

Li, R., Li, L., & Wang, Q. (2022b). The impact of energy efficiency on carbon emissions: Evidence from the transportation sector in Chinese 30 provinces. *Sustainable Cities and Society, 82*, 103880.

Liu, Z., He, J., Zhang, C., Yan, X., & Zhang, H. (2022). Optimal off-ramp terminal locating strategy based on traffic safety and efficiency. *Transportation Letters, 14*(2), 174–185.

López-Casasnovas, G., & Soley-Bori, M. (2014). The socioeconomic determinants of health: Economic growth and health in the OECD countries during the last three decades. *International Journal of Environmental Research and Public Health, 11*(1), 815–829.

Mahmood, H., Alkhateeb, T. T. Y., & Furqan, M. (2020). Industrialization, urbanization and CO2 emissions in Saudi Arabia: Asymmetry analysis. *Energy Reports, 6*, 1553–1560.

Mealy, P., & Teytelboym, A. (2020). Economic complexity and the green economy. *Research Policy*, 103948.

Mowafi, H., Rice, B., Nambaziira, R., Nirere, G., Wongoda, R., James, M., Bisanzo, M., GECC Writing Group, Bisanzo, M., &, Post, L. (2021). Household economic impact of road traffic injury versus routine emergencies in a low-income country. *Injury*.

Nadrian, H., Mahmoodi, H., Taghdisi, M. H., Aghemiri, M., Babazadeh, T., Ansari, B., & Fathipour, A. (2020). Public health impacts of urban traffic Jam in Sanandaj, Iran: A case study with mixed-method design. *Journal of Transport & Health*, 19, 100923. https://doi.org/10.1016/j.jth.2020.100923

Nathaniel, S. P., Murshed, M., & Bassim, M. (2021). The nexus between economic growth, energy use, international trade and ecological footprints: the role of environmental regulations in N11 countries. *Energy, Ecology and Environment*, 1–17.

Neagu, O., & Teodoru, M. C. (2019). The relationship between economic complexity, energy consumption structure and greenhouse gas emission: Heterogeneous panel evidence from the EU countries. *Sustainability, 11*(2), 497.

Ozkan, O., & Atli, O. (2021). Transporting COVID-19 testing specimens by routing unmanned aerial vehicles with range and payload constraints: The case of Istanbul. *Transportation Letters, 13*(5–6), 482–491.

Pani, A., Sahu, P. K., & Holguín-Veras, J. (2021). Examining the determinants of freight transport emissions using a fleet segmentation approach. *Transportation Research Part D: Transport and Environment, 92*, 102726.

Pata, U. K. (2021). Renewable and non-renewable energy consumption, economic complexity, CO 2 emissions, and ecological footprint in the USA: Testing the EKC hypothesis with a structural break. *Environmental Science and Pollution Research, 28*(1), 846–861.

Pesaran, M. H. (2004). General diagnostic tests for cross-sectional dependence in panel data. Cambridge University Working Paper. Econ. 0435). Doi: 17863/CAM.5113.

Pesaran, M. H. (2006). Estimation and inference in large heterogeneous panels with a multifactor error structure. *Econometrica, 74*(4), 967–1012.

Pesaran, M. H., & Yamagata, T. (2008). Testing slope homogeneity in large panels. *Journal of Econometrics, 142*(1), 50–93.

Peters, W. R., & deBeche-Adams, T. (2022). Healthcare economics. In *The ASCRS textbook of colon and rectal surgery* (pp. 1117–1126). Springer.

Pu, X., Zeng, M., & Luo, Y. (2021). The effect of business cycles on health expenditure: A story of income inequality in China. *Frontiers in Public Health, 9*, 160.

Purewal, K., & Haini, H. (2021). Re-examining the effect of financial markets and institutions on economic growth: evidence from the OECD countries. *Economic Change and Restructuring*, 1–23.

Qehaja, S. S., Qehaja, D., Arber, H. O. T. I., & Marovci, E. (2023). The relationship between government health expenditure and economic growth: Evidence from western Balkan countries. *International Journal of Applied Economics, Finance and Accounting, 15*(1), 10–20.

Radmehr, R., Henneberry, S. R., & Shayanmehr, S. (2021). Renewable energy consumption, CO2 emissions, and economic growth nexus: A simultaneity spatial modeling analysis of EU countries. *Structural Change and Economic Dynamics, 57*, 13–27.

Raghupathi, V., & Raghupathi, W. (2020). Healthcare expenditure and economic performance: Insights from the United States Data. *Frontiers in Public Health, 8*, 156.

Rasendran, C., Li, A., & Singh, R. P. (2022). Incremental health care expenditures associated with Glaucoma in the United States: A propensity score–matched analysis. *Journal of Glaucoma, 31*(1), 1–7.

Rokicki, T., Bórawski, P., Bełdycka-Bórawska, A., Żak, A., & Koszela, G. (2022). Development of electromobility in European union countries under COVID-19 Conditions. *Energies, 15*(1), 9.

Romero, J. P., & Gramkow, C. (2021). Economic complexity and greenhouse gas emissions. *World Development, 139*, 105317.

Saelens, B. E., Meenan, R. T., Keast, E. M., Frank, L. D., Young, D. R., Kuntz, J. L., Dickerson, J. F., & Fortmann, S. P. (2022). Transit use and health care costs: A cross-sectional analysis. *Journal of Transport & Health, 24*, 101294.

Saha, S. (2022). Healthcare expenditure and economic development dynamics in India: Experiences from COVID-19 pandemic. In *Economic and societal transformation in pandemic-trapped India: Emerging challenges and resilient policy prescriptions* (pp. 203–225). Springer Nature Singapore.

Saud, S., Haseeb, A., Zafar, M. W., & Li, H. (2023). Articulating natural resource abundance, economic complexity, education and environmental sustainability in MENA countries: Evidence from advanced panel estimation. *Resources Policy, 80*, 103261.

Sengupta, S. (2022). Empirical evidence to the nonmonotonic relationship between public health expenditure and economic growth. *Theoretical and Applied Economics*, *29*(1(630, Spring), 49–62.

Shahadin, M. S., Mutalib, N. S. A., Latif, M. T., Greene, C. M., & Hassan, T. (2018). Challenges and future direction of molecular research in air pollution-related lung cancers. *Lung Cancer, 118*, 69–75. https://doi.org/10.1016/j.lungcan.2018.01.016

Shahzad, U., Elheddad, M., Swart, J., Ghosh, S., & Dogan, B. (2023). The role of biomass energy consumption and economic complexity on environmental sustainability in G7 economies. *Business Strategy and the Environment, 32*(1), 781–801.

Shahzad, U., Ferraz, D., Doğan, B., & do Nascimento Rebelatto, D. A. (2020). Export product diversification and CO_2 emissions: Contextual evidences from developing and developed economies. *Journal of Cleaner Production, 276*, 124146.

Shahzad, U., Radulescu, M., Rahim, S., Isik, C., Yousaf, Z., & Ionescu, S. A. (2021). Do environment-related policy instruments and technologies facilitate renewable energy generation? Exploring the contextual evidence from developed economies. *Energies, 14*(3), 690.

Simic, V., Gokasar, I., Deveci, M., & Karakurt, A. (2022). An integrated CRITIC and MABAC based Type-2 neutrosophic model for public transportation pricing system selection. *Socio-Economic Planning Sciences, 80*, 101157.

Sun, X., Wandelt, S., Zheng, C., & Zhang, A. (2021). COVID-19 pandemic and air transportation: Successfully navigating the paper hurricane. *Journal of Air Transport Management*, 102062.

Ullah, I., Ali, S., Shah, M. H., Yasim, F., Rehman, A., & Al-Ghazali, B. M. (2019). Linkages between trade, CO2 emissions and healthcare spending in China. *International Journal of Environmental Research and Public Health, 16*(21), 4298. https://doi.org/10.3390/ijerph16214298

Usman, M., & Jahanger, A. (2021). Heterogeneous effects of remittances and institutional quality in reducing environmental deficit in the presence of EKC hypothesis: A global study with the application of panel quantile regression. *Environmental Science and Pollution Research, 28*(28), 37292–37310. https://doi.org/10.1007/s11356-021-13216-x

Usman, M., & Makhdum, M. S. A. (2021). What abates ecological footprint in BRICS-T region? Exploring the influence of renewable energy, non-renewable energy, agriculture and financial development. *Renewable Energy*. https://doi.org/10.1016/j.renene.2021.07.014

Usman, M., Makhdum, M. S. A., & Kousar, R. (2020). Does financial inclusion, renew- able and non-renewable energy utilization accelerate ecological footprints and economic growth? Fresh evidence from 15 highest emitting countries. *Sustainable Cities and Society*, *65*, 102590. https://doi.org/10.1016/j.scs.2020.102590

Usman, M., Anwar, S., Yaseen, M.R., Makhdum, M.S.A., Kousar, R., & Jahanger, A. (2021a). Unveiling the dynamic relationship between agriculture value addition, energy utilization, tourism and environmental degradation in South Asia. *Journal of Public Affairs*, 1–15. https://doi.org/10.1002/pa.2712

Usman, M., Khalid, K., & Mehdi, M.A. (2021b). What determines environmental deficit in Asia? Embossing the role of renewable and non-renewable energy utilization. *Renewable Energy*. https://doi.org/10.1016/j.renene.2021.01.012

Vanova, D., & Wood, R. (2020b). The unequal distribution of household carbon footprints in Europe and its link to sustainability. *Global Sustainability*, *3*.

Vyas, V., Mehta, K., & Sharma, R. (2023). The nexus between toxic-air pollution, health expenditure, and economic growth: An empirical study using ARDL. *International Review of Economics & Finance, 84*, 154–166.

Wan, Y., Chen, X., Liu, Q., Hu, H., Wu, C., & Xue, Q. (2022). Informal landfill contributes to the pollution of microplastics in the surrounding environment. *Environmental Pollution, 293*, 118586.

Wang, F., Wu, M., & Wang, J. (2023). Can increasing economic complexity improve China's green development efficiency? *Energy Economics, 117*, 106443.

Wang, D. D. (2019). Assessing road transport sustainability by combining environmental impacts and safety concerns. *Transportation Research Part D: Transport and Environment, 77*, 212–223.

WHO (World Health Organization) (2019): Ten threats to global health.

Yang, B., Jahanger, A., Usman, M., & Khan, M. A. (2021a). The dynamic linkage between globalization, financial development, energy utilization, and environmental sustainability in GCC countries. *Environmental Science and Pollution Research, 28*(13), 16568–16588. https://doi.org/10.1007/s11356-020-11576-4

Yang, X., Wu, H., Ren, S., Ran, Q., & Zhang, J. (2021b). Does the development of the internet contribute to air pollution control in China? Mechanism discussion and empirical test. *Structural Change and Economic Dynamics, 56*, 207–224.

Zaman, K., Anser, M. K., Awan, U., Handayani, W., Salamun, H., Abdul Aziz, A. R., Jabor, M. K., & Subari, K. (2022). Transportation-induced carbon emissions jeopardize healthcare logistics sustainability: Toward a healthier today and a better tomorrow. *Logistics, 6*(2), 27.

Zeqiraj, V., Sohag, K., & Soytas, U. (2020). Stock market development and low-carbon economy: The role of innovation and renewable energy. *Energy Economics, 91*, 104908.

Zhao, C., Wang, K., Dong, X., & Dong, K. (2022). Is smart transportation associated with reduced carbon emissions? The Case of China. *Energy Economics, 105*, 105715.

Zheng, S., Wang, R., Mak, T. M., Hsu, S. C., & Tsang, D. C. (2021). How energy service companies moderate the impact of industrialization and urbanization on carbon emissions in China? *Science of the Total Environment, 751*, 1416. https://doi.org/10.1016/j.scitotenv.2020.141610

Authors and Affiliations

Zahid Hussain[1] (ORCID) **· Bihizi Marcel[2] · Abdul Majeed[3] ·**
Raymondo Sandra Marcelline Tsimisaraka[3]

Bihizi Marcel
bahimarce@yahoo.fr

Abdul Majeed
abdulmajeed192@hotmail.com

Raymondo Sandra Marcelline Tsimisaraka
Sandra.raymondo@hgnu.edu.cn

[1] School of Finance, Qilu University of Technology (Shandong Academy of Sciences), Jinan, People's Republic of China

[2] Kigali Independent University, Kigali, Rwanda

[3] Business School, Huanggang Normal University, Hubei, People's Republic of China