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Abstract: This paper explores the relationship between transportation infrastructure and CO_2 emissions by incorporating business cycle, transportation energy consumption and oil prices in carbon emissions function for the U.S. economy using monthly data for the period of 2000M1-2017M12. We have applied ADF unit root test accommodating structural breaks in the series developed by Kim and Perron (2009). We have applied bounds testing approach to cointegration developed by Pesaran et al. (2001) to examine cointegration between the variables. The empirical results confirm the existence of cointegration relationship between the variables. Moreover, transportation infrastructure decreases carbon emissions. Business cycle impedes environmental quality by increasing carbon emissions. Transportation energy consumption is positively linked with transportation carbon emissions but oil prices decrease it. Inverted U-shaped Transportation Kuznets curve (TKC) is found between transportation infrastructure and carbon emissions. The relationship between business cycle and CO_2 emissions is an inverted-U shaped validating the environmental Kuznets curve (EKC). The causality analysis reveals the presence of feedback effect between transportation infrastructure and CO_2 emissions. Similarly, economic activity causes carbon emissions and in resulting, carbon emissions cause business cycle i.e. bidirectional causality. These empirical findings show new policy directions for using transportation infrastructure as economic tool to achieve growth along with sustainable environment.

Keywords: Transport Infrastructure, Business Cycle, Transport Energy, CO_2 Emissions

JEL Classifications: F11, R11, K32, Q56

1. Introduction

Transportation sector integrates movement of people and goods across cities and localities of the United States via road, rail, ship and airplane. It plays a vital role for the U.S. economy in terms of employing nearly 10 million people[1] and accounting for 8.9% of U.S. GDP in 2015[2]. Greene and Schafer (2003) in their global climate change report also find that transportation sector accounts for nearly a third of U.S.'s total greenhouse gas emissions. Lawson and Ahmed (2018) further indicate that since 2016, transportation sector has been the biggest source of U.S. greenhouse gas emissions. Road transport is the major contributor of carbon emissions (75%)[3] in U.S. economy which mainly comes from the transportation sector as it derives over 90% of its consumable energy from the petroleum product. This shows that United States' emissions in the transportation sector is growing rapidly. Subsequently, the Great Plains Institute recently argues that the U.S. now produces more greenhouse gas emissions from transportation sector than from electric power production[4]. This is not the case with mid-century goal which states that we can decarbonize the transportation sector for any economy to bring sector emissions to zero-or-negative through substitute fuels of petroleum product (e.g. natural gas, bio-fuels and electricity) and carbon capture technology (Lawson and Ahmed, 2018).

However, with passing globalization and changing production pattern, it is clear that the scale of U.S.'s economy has continued to increase with the use of higher carbon fuels and the lack of vehicle efficiency in transportation sector. Perhaps, the scaling expansion may benefit the U.S. economy but at the cost of environmental quality through increased carbon emissions due to rise in road energy consumption in transportation sector. This further shows the multifaceted decarbonisation challenges for the U.S. economy facing in the 21st century of the world. If transportation sector's energy consumption is not considered in the policy making portfolio, then the developed economy like United States is going to face the bigger threat of environmental consequences of climate change and global warming in the long-run. This will also pose an unbearable threat for other developed and developing economies. Given that consequences, not only the nexus between economic growth and natural environment has always been a complex and challenging issues for policy makers, economists and environmental scientists of the connected world, but also an empirical exploration on the nexus between transportation sector and carbon emissions is an urgent issue which has been recently marked in the study of Lawson and Ahmed (2018). They argued that as of 2016, transportation is the United States' largest direct source of green-house gas emissions. This not only motivates us to study the relationship between transportation infrastructure and CO_2 emissions by incorporating business cycle, transportation energy consumption and oil prices in carbon emissions function for the U.S. economy using monthly data over the period of 01-2000-12-2017 but also enables us to verify the seminal inverted-U shaped hypothesis of Kuznets (1955).[5] From the climate change policy perspective, an empirical analysis of the

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[1] U.S. Bureau of Labor Statistics, (BLS), Occupational Employment and Wages, May 2017, (Washington, DC: BLS, 2017), https://www.bls.gov/oes/current/oes530000.htm#(1)

[2] U.S. Bureau of Transportation Statistics (BTS), Freight Facts & Figures 2017 – Chapter 5: Economic Characteristics of the Freight Transportation Industry, (Washington, DC: BTS, 2017) https://www.bts.gov/bts-publications/freight-facts-and-figures/ freight-facts-figures-2017-chapter-5-economic.

[3] The road being the sub-sector of transportation sector during 2015, is by far producing the greatest emissions (75%) which includes motorcycles (<1%), buses (1%), medium and heavy duty trucks (20%), light duty trucks (16%), and passengers vehicles (38%) (See for Lawson and Ahmed, 2018). In additions, ships and boats account for 2% to transportation sector emissions followed by rail (2%) and aircraft (8%).

[4] http://www.betterenergy.org/

[5] Influenced by the seminal work of Kuznets (1955) linking the inverse relationship between economic growth and income inequality, there has been a growing literature to test the validity of inverted-U shaped Environmental Kuznets curve (EKC) between economic growth and environmental quality (Kuznets 1995,

relationship between transportation sector and transport-driven carbon emissions is very significant for developed countries like U.S. as it can be a way to predict decarbonisation paths within zero emissions forecasting models, and therefore it can assist policy makers in designing desirable policy for improving environmental quality in the long-run. In light of this policy importance, it is essential to understand the causal linkage between transportation infrastructure and carbon emissions in U.S. It is also believed on the basis of inverted U-shaped Transportation Kuznets Curve that transportation infrastructure plays a vital role in the reduction of carbon emissions mainly in the long-run. This happens when the U.S. government implements the stringent transport regulation for the travellers only to use their electric vehicles on road or direct the airlines to use energy saving technology for the betterment of air quality. The use of electricity vehicles and energy saving technology will enable the U.S. economy to have a better quality of natural environment via reduction of excessive energy usage. It is also argued that the reduction of air pollution coming from the growth of transportation sector is important for achieving the goals of climate change and sustainable development in long-run.

Given the above background, it is important to study the role of transportation sector growth on carbon emissions for the U.S. economy. The empirical exercise towards the causal linkage of transportation sector growth and carbon emissions in U.S. is scarce in existing literature of the subsequent section 2. Hence this study is motivated to explore the relationship between transportation infrastructure and CO_2 emissions by incorporating business cycle, transportation energy consumption and oil prices in carbon emissions function for the U.S. economy using monthly data for the period of 2000-2017. We have applied ADF unit root test accommodating structural breaks in the series developed by Kim and Perron (2009). We have applied bounds testing approach to cointegration developed by Pesaran et al. (2001) to examine cointegration between the variables. The empirical results confirm the existence of cointegration relationship between the variables. Moreover, transportation infrastructure decreases carbon emissions. Business cycle impedes environmental quality by increasing carbon emissions. Transportation energy consumption is positively linked with transportation carbon emissions but oil prices decrease it. Transportation Kuznets curve (TKC) is found between transportation infrastructure and carbon emissions. The relationship between business cycle and CO_2 emissions is an inverted U-shaped validating the environmental Kuznets curve (EKC). The causality analysis reveals the presence of feedback effect between transportation infrastructure and CO_2 emissions. Similarly, economic activity causes carbon emissions and in resulting, carbon emissions cause business cycle i.e. bidirectional causality. In doing this, this study contributes to the existing literature and also provides the policy insights for policymakers and governments in U.S.

Grossman and Krueger 1991). The basic idea of inverted-U shaped EKC hypothesis suggests that in the early stage of economic development, environmental quality deteriorates, and subsequently environmental quality improves with economic growth. This further shows that the people with high income level demand better environment quality than the people with low income level. This is true because the people with low income level come under the poor category where they demand more of basic necessities like food, cloth and shelter, whereas the people with higher income come under the rich category where they demand better education and environmental quality in long-run. Therefore, economic growth/level of economic development could be a demanding necessary solution that can ensure cleaner environment in the long run. But this may not be a permanent solution based on the empirical literature. Hence, it is being argued that the existing empirical literature though provides interesting insights but a consensus between transportation sector and carbon emissions is yet to be reached for the improvement and management of environmental crisis of the United States in the long-run. In line with the seminal work of Kuznets EKC hypothesis, someone can also hypothesize that the initial growth of transportation infrastructure increases carbon emissions and decreases it after reaching the threshold point which is known as inverted U-shaped Transportation Kuznets Curve (TKC).

The rest of paper is organised as following: Section-2 details review of literature. Section-3 shows model construction and data collection. The methodological strategy is explained in Section-4 and results are interpreted in Section-5. Section-6 deals with conclusion and policy implications.

2. Literature Review

Studying the drivers of environmental degradation is not new in the field of environmental economics. There is a plenty of empirical examinations of Environmental Kuznets Curve (EKC) hypothesis using variation in the choice of environment indicators like SO_2, SPM, CO_2, nitrogen oxide and etc., using specific country or group of countries and utilizing different econometrics methods. Most works seem to validate an inverted U-shaped relation between income and these indicators. In what follows, we will focus our review on examining the environmental cost of transportation for the U.S. economy. Specifically, we will explore the relationship between transportation infrastructure and CO_2 emissions by incorporating business cycle, energy consumption and oil prices in carbon emissions function for the U.S. economy. Therefore, we will first review studies that examined the relation between business cycle phases and environmental quality. Then, we will review studies that dealt with the effects of transportation infrastructure, transport energy consumption and oil prices on environmental quality.

2.1. The Effects of Business Cycle Phases on Carbon Emissions

It is important to mention that making an implicit assumption of a constant elasticity of emissions, in some of the studies, with respect to economic output has been criticized as variation of such elasticity over distinct phases of business cycle, and across different cycles, would most likely impose some uncertainties in making accurate forecasts on predicting emissions level (Sheldon, 2014). Furthermore, there is slight information as to whether the relationship between economic growth and environment is symmetric across business cycle phases or it is not. An insignificant number of studies have appeared in recent years to inspect the connection between carbon emissions and economic growth over business cycle phases. One can argue that the relationship between carbon emissions and business cycle can either be pro-cyclical or counter-cyclical. While pro-cyclical means that there is an inclination for emissions to increase beyond their trend during periods of economic expansion and similarly decrease during periods of economic recession, counter-cyclical implies the opposite. The rational is very straight-forward, as the level of economic activities increases during expansion, one would expect that the level of emissions associated with it to rise. During contraction of economic activities, the level of emissions associated with lower output level will tend to decline.

For instance, Heutel (2012) developed and estimated a dynamic stochastic general equilibrium model using the calibration approach of estimating business cycles for the U.S. economy. Their results indicated that the cyclical component of carbon emissions and the United States' GDP, using quarterly data or monthly data 1981-2003, was found to be inelastic. Carbon emissions were found to be pro-cyclical, increasing during expansions and decreasing during contractions and more volatile than GDP. Fischer and Springborn (2011) used a dynamic stochastic general equilibrium model to study the impacts of emissions cap, emissions tax and intensity target that established a maximum emissions-output ratio. Their results showed that an intensity target boosts greater economic growth than either a cap or tax. Moreover, emissions are still found to be pro-cyclical despite the regulations emissions. Doda (2014) used the Hodrick-Prescott (HP) filter to find the cyclical components of carbon emissions and GDP for a sample of 122 countries using annual data, 1950-2011. The study reported that emissions are found to be pro-cyclical and cyclically more volatile than GDP where the cyclical component of emissions is on average found to be about 3 times more volatile than that of GDP. In addition, the cyclical volatility of emissions was found to be negatively correlated with GDP per capita across countries while pro-cyclicality of emissions was found to be positively correlated with GDP across countries. Nonetheless, in 15 countries results indicated that existence of counter-cyclical relationship. York (2012) used annual data for 154-160 countries for the period 1960-2008 utilizing panel econometrics technique to examine the business cycle effects on energy and carbon emissions. The study reported that CO_2 emissions per capita rises at a higher rate during periods when there is positive GDP per capita growth than the rate at which it declines when there is a negative GDP per capita growth. Thoma (2004) employed United States monthly data on electrical energy usage for the period 1973–2000 to examine its relationship with the U.S. business cycle. The study reported that as the economy passages from a peak into an economic downturn, the commercial and industrial sectors experience noteworthy drops in energy use. Likewise, during periods of economic boom, these sectors observe a significant increase in energy usage. Nonetheless, consumers might be more resilient in recession than is industry in the use of energy.

Peters et al. (2012) used annual data (1960-2010), for developed and developing countries to examine the effect of the 2008-09 global financial crisis on carbon emissions. They reported that the decline in CO_2 emissions due to the 2008–09 crisis was brief as emissions return to normal again in 2010. Jotzo et al. (2012) using annual global annual data (1972-2010) found that rising energy intensity together with an increase in carbon intensity led to increase in emissions in 2010. Jiang and Li (2017), using a multilevel logarithmic mean division index method inspected the drivers of carbon dioxide emissions and the decoupling status of electricity in the United States. Their results showed that electricity power production effect applied a positive role in the increase of carbon emissions while energy mix effect and conversion efficiency effect contributed to limiting emissions. Alege et al. (2017) investigated the cyclical components of carbon emissions and real business cycles in Nigeria employing data for 1981-2015. Their results revealed that there is a pro-cyclical relationship between emissions and agricultural and industrial sectors while reporting a counter-cyclical relationship with total output. Shahiduzzaman and Layton (2015), examined the asymmetry of changes in CO_2 emissions over the business cycle of the USA utilizing yearly data from 1949 and monthly data from 1973 to 2013. The decomposition analysis is used to study the relative roles of various proximate contributing features to observed changes in total and per capita CO_2 emissions and emissions intensity, over business cycle phases. Their reported results suggested that aggregate emissions and emissions intensity decrease much faster in contractions than they rise in expansions. Furthermore, they reported that in most recent, post financial crisis, US expansion, emissions per capita have continue their decline at a rate very comparable to that of reduction in preceding contractions. They concluded that the most recent contraction may have continued to impact the path of per capita emissions well beyond the instant impact observed during the contraction itself. Mi et al. (2017) studied the drivers of carbon emissions flow among Chinese western and eastern provinces since the global financial crisis. They have found that the patterns of carbon emissions flow have changed greatly after financial crisis and also argued that western province in China has shifted from net carbon emission exporter to net carbon emission importer. Both rising domestic consumption and infrastructure development are driving forces of carbon emissions in western province of China.

Therefore, most studied reviewed seem to suggest that carbon emissions are pro-cyclical to output. That is, there is the tendency for emissions to rise beyond their trend during periods of economic expansion and similarly fall during periods of economic recession. Furthermore, one can conclude by saying that there is relatively a limited number of studies examining the business cycle effects on carbon emissions. This could be due to the limited knowledge on the relative importance of driving forces in business cycle phases. Furthermore, most of the limited available studies have relied primarily on yearly data and therefore may have ignored the exact specification of business cycle turning point dates. This is important as some business cycle downturns are found to be short lived, typically less than one year, and the phase change shapes can vary extensively across countries, calling for using monthly data as being more appropriate in examining the forces that initiate emissions in each business cycle phase.

2.2. The Effects of Transportation Infrastructure, Transport Energy Consumption and Oil Prices on Carbon Emissions

In promoting economic growth, many economies confront the pressures of providing and maintaining an effective transportation infrastructure. The development of this infrastructure reduces transportation costs and transit time, and promotes inter-regional communication. It facilitates the expansion of regional markets and population, which is necessary to promote regional economic growth and technological improvements. Therefore, transportation is seen to have direct and indirect effects that are positively related to economic growth (Mohmand et al., 2016; Subhra and Nath, 2017). A study of Liddle (2012) suggests that transport sector has long-run relationship with income.

Considering the above, many governments have devoted enormous attention and scarce resources to improving the scope and operation of its transportation infrastructure on the presumption that is a pre-condition for sustained economic growth. Transportation being a significant focus in our daily lives, as individuals, governments and companies make transport-related choices daily, and with increasing flows of people, products, and services throughout the globe, transportation will continue to be increasingly relevant to our economies. Therefore, this undeniable relationship between transport and the economy will continue to pose challenges to policymakers when it comes to designing and forecasting desirable future sustainable transport policies. Transportation contributes to economic activity by providing the infrastructure that supports the movement of people and goods, while it promotes human and economic development by providing greater mobility, it is also a reflection of the stage of an economy’s progression rate. Domestic and global transportation systems are altering all features of human life, from manufacturing, trade, defense, education, entertainment, tourism, and culture among developed and developing economies. The theoretical view is very straight forward, development of such infrastructure cuts transportation costs and transit time to carry products and people, and therefore helps inter-regional and global communication. This eases the expansion of regional and international markets which is essential to promote economic growth and technological improvement.

Emerging economies are probably more aware of the importance of an effective transport sector with its direct and indirect effects on contributing positively to economic growth and development via transforming resources into products, knowledge and communication (Mohmand et al., 2016; Subhra and Nath, 2017). A study of Liddle (2012) suggests that transport sector has long-run relationship with income. Despite the above-mentioned benefits, the relationship between transport and economic growth is far from being that simple as the construction of transportation infrastructure has affected the level of urban carbon emissions creating challenges to policymakers when it comes to planning future sustainable transport policies. This lessens the values of benefits resulting from transportation and also shows the need for the creation of effective development of carbon-abatement policies while also maintaining a growth in the level of transportation infrastructure required to achieve desired level of growth. Although empirical research on the effects of transportation infrastructure, transport energy consumption and oil prices on environmental quality is lacking, some empirical studies have considered these issues in recent years. In the past few years, this issue has attracted the attention of researchers and policymakers in the fields of economics, transportation and environment because of the growing share of transportation emissions in the overall emissions (Timilsina and Shrestha, 2009a, 2009b). For example, Xu and Lin (2018) used a quantile regression method to study the reasons of the difference in CO_2 emissions under high, medium and low level of development in China's 30 provinces using panel data from 2000 to 2015. These provinces were divided into 6 groups, i.e. the lower 10th, 10th-25th, 25th-50th, 50th-75th, 75th-90th and upper 90th quantile provinces. Their results reported that the impacts of economic growth and energy intensity on CO_2 emissions in the 25-50th quantile provinces are higher than those in the other quantile provinces. The effects of urbanization and freight turnover in the upper 90th and 75th-90th quantile provinces were found higher than those in other quantile provinces. Finally, the effects of passenger turnover in the lower 10th and 10th-25th quantile provinces were found to be the highest in all the quantile provinces. Pablo-Romero et al. (2017) estimated Kuznets curves using panel data covering the EU27 countries over the period of 1995-2009 for total transport energy use, household transport energy use, and productive transport energy use in absolute and per capita energy use. They further considered, as per hour worked, the relationship between productive transport energy use and gross value-added by controlling energy prices and differences in economic structures. Their results showed that the elasticity of transport energy use with respect to gross value added in per capita terms is found to be decreasing from a threshold for the three transport energy consumption variables, nonetheless the turning point of improved environmental quality was not reached in any case.

Danish and Baloch, (2017) examined the linkages between road transport energy consumption, economic growth, and environmental quality in Pakistan using Sulfur dioxide (SO_2) emissions from transport sector as a new proxy for environmental quality. Their results showed that road infrastructure increases economic growth. Further, they found that road infrastructure and urbanization hinder environmental quality. Their results called for the need for appropriate measures to tackle the adverse effects of transportation infrastructure on environment. Katirioglu, (2017) examined the effect of oil prices movements in conventional EKC of Turkey using annual figures covering the 1960–2010 period. The study reported that oil prices and carbon emissions are in long-term equilibrium relationship. Furthermore, the impact of oil prices on carbon emissions are found to be negative indicating that rises in oil prices would lead to drop in carbon emissions. Daldoul and Dakhlaoui (2016) performed a decomposition of CO_2 emissions from highway transportation in Tunisia using data from 1980 to 2011. They explored the contributions of emissions coefficient, vehicle fuel intensity, vehicle ownership, population expansion and economic productivity to the rise of highway transportation CO_2 emissions in the country. They reported results showed that economic growth and vehicle ownership were key factors contributing to the augmentation of CO_2 emissions in Tunisia while population intensity has significantly contributed to decrease of CO_2 emissions. They recommended that steps be taken to decouple road activity from economic growth in the country by shifting to rail. This recommendation is also consistent with the finding of Song et al. (2016b) where they find an increasing environmental efficiency in eastern region of China due to massive use of railway transport.

Alshehry and Belloumi (2015) examined the dynamic causal relationship between energy consumption, energy prices and economic activity in Saudi Arabia using a Johansen multivariate cointegration approach and incorporate CO_2 emissions as a control variable. They confirmed the existing of a long-run relationship between energy consumption, energy prices, carbon emissions, and economic growth. Their empirical analysis confirmed a long-run unidirectional causality running from energy prices to economic growth and CO_2 emissions and a short-run unidirectional causality from energy prices to CO_2 emissions. Shahbaz et al. (2015) used the ARDL approach to investigate the causal relationship between transportation energy consumption, fuel prices, transport sector value added and CO_2 emissions in Tunisia for the period of 1980–2012. Their empirical results supported a bidirectional causal relationship between energy consumption and CO_2 emissions. Furthermore, bidirectional causality is also found between road infrastructure and CO_2 emissions. The bidirectional causality is also found between transport value-added and CO_2 emissions. They also reported that fuel prices cause CO_2 emissions, energy consumption, road infrastructure and transport value-added in Granger sense. Liddle (2015) studied the relationship between GDP per capita growth and three urban transport-related emissions (CO, VHC, and NOx) using data from 84 cities. The results reveal that per-capita emissions first increase and then started to decline at observed income levels. Though, for urban consumed transport energy, the estimated turning point was found to be well beyond the sample bounds. Sobrino and Monzon (2014) attempted to identify the factors influencing emissions of road transport in Spain during the period from 1990 to 2010 including traffic activity, fuel economy and socioeconomic development. Their results indicated that economic growth of Spain has been strictly connected to the rise in emissions during 2008-9 economic crisis road traffic emissions in Spain decreased. They cited the reduction of road transport and improvement in energy efficiency as the main contributors to this decline. Zhao et al. (2014) investigated the factors of energy related, carbon dioxide emissions intensity among 30 provinces in China for the period 1991-2010 using a novel spatial panel data models. Their results suggested that per-capita GDP decreases CO_2 emissions intensity, which may indicate that encouraging the local economic development, may reduce CO_2 emissions intensity. An increase in population density was found to lead to a decline of CO_2 emissions intensity while an increase in the length of highways leads to an increase of such intensity. They report that China's energy prices have no significant effect on CO_2 emissions intensity. They suggest that country's policies like subsidies and price controls may have artificially lowered energy prices and caused it to have effect on CO_2 emissions intensity. Finally, they report that per-capita GDP, population density, and total length of highways shows a significant effect on both the own province and the neighbouring province elasticities. Liddle and Lung (2013) used panel methods that mitigate heterogeneity and cross-sectional dependence to show the direction and sign of long-run causality between transport energy consumption per capita and real GDP per capita using a sample of 107 countries for the period of 1971–2009. The Granger causality was determined to run from GDP per capita to transport energy per capita consumption. Andreoni and Galmarini (2012) utilized a decomposition analysis to study the main factors prompting CO_2 emissions of European transport activities for the period 2001–2008. Their results claimed that economic growth is the key factor, which influences CO_2 emissions in aviation and water transport of EU-27.

Sadorsky, (2009) estimated a model of renewable energy consumption for the G7 countries. The results showed that rises in real GDP per capita and CO_2 emissions per capita are a key driver behind per capita renewable energy consumption in the long term. Furthermore, oil prices surges have a smaller negative effect on renewable energy consumption. Timilsina and

Shrestha, (2009a) examined the factors accountable for the growth of transport sector CO_2 emissions in twenty Latin American and Caribbean (LAC) countries during the 1980-2005. They decomposed the emissions growth into components associated with changes in fuel mix, modal shift and economic growth, changes in emissions coefficients and transportation energy intensity. Their empirical findings reveal that economic growth and changes in transportation energy intensity are the principal reasons driving transport sector CO_2 emissions growth in the countries considered. Specifically, economic growth was found to be responsible for the growing drift of transport sector CO_2 emissions in Argentina, Brazil, Costa Rica, Peru and Uruguay. Tanishita (2006) studied EKC for energy intensity from passenger transport, utilizing city-based data covering the period of 1980-1995. The study reported results reinforced the EKC relationship between energy intensity of private and public transport and per capita gross regional product. The break point ranged from US\$22,000 to US\$26,000 (PPP, 1995). Liddle (2004) using a data panel of 23 Organization for Economic Co-operation and Development (OECD) countries, with over 10-year intervals from 1960 to 2000 investigated the EKC relationship between per capita road energy use and per capita GDP. Geographic and demographic variables were included and three forms of the model were estimated. The EKC hypothesis was rejected for all the models, and the relation between per capita road energy use and per capita GDP was found to be monotonic.

The studies reviewed above have reported conflicted results in the relationship between environmental quality and transportation infrastructure, road transport energy consumption and oil prices. While in some countries energy prices were found to have no significant effect on CO_2 emissions intensity, in others opposite results were obtained. Furthermore, while bidirectional causality was reported between transportation infrastructure and CO_2 emissions in some studies, other research in the literature revealed different results. In any case, road infrastructure and what it causes in further road energy consumption are still among the greatest suppliers to emissions of transport sector which pollutes environment. Nonetheless, road infrastructure and energy consumption are the vital determinants of sustainable development and economic growth.

3. The Modelling and Data

3.1. Empirical Modelling

Existing literature provides various empirical studies investigating the determinants of transport carbon emissions. For instance, Shahbaz et al. (2015) used fuel prices, transport value-added per capita, energy consumption, road transport energy consumption and road infrastructure as determinants of road carbon emissions. Alshehry and Belloumi (2016) employed road transport energy consumption and real GDP per capita as determining factors of road CO_2 emissions. Xu and Lin (2018) employed population, economic growth and energy intensity as major factors of transport carbon emissions for Chinese provinces. The empirical results of such studies are conflicting which provides rational for researchers to investigate the effect of business cycle, transport infrastructure, transport energy consumption and energy prices on transport carbon emissions for the case of the USA. The general form of transport carbon emissions function is modelled as following:

$$C_t = f(Y_t, T_t, E_t, EP_t) \tag{1}$$

where, C_t is transport carbon emissions, Y_t is business cycle proxies by industrial production index[6], EP_t is crude oil prices, E_t is transport energy consumption and T_t is transport

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[6] Gozgor et al. (2019) also used industrial production index as measure of business cycle.

infrastructure. We have transformed all the variables into natural-log for efficient and reliable empirical results. The empirical form of transport carbon emissions function is modelled as following:

$$\ln C_t = \beta_0 + \beta_1 \ln T_t + \beta_2 \ln Y_t + \beta_3 \ln E_t + \beta_4 \ln EP_t + \mu_i \tag{2}$$

where $\ln$ is natural-log and μ_i is error term supposed to be independent and identically distributed (iid). Business cycle is positively lined with transport carbon emissions if $\beta_1 > 0$ otherwise business cycle and transport carbon emissions are negatively linked. $\beta_2 > 0$ shows that crude oil prices have positive effect on transport CO_2 emissions otherwise $\beta_2 < 0$. The relationship between energy consumption and carbon emissions in transportation is positive if $\beta_3 > 0$ otherwise $\beta_3 < 0$. Transportation infrastructure is positively linked with carbon emissions if $\beta_3 > 0$ otherwise transportation infrastructure improves environmental quality by lowering carbon emissions i.e. $\beta_3 < 0$.

We have augmented equation-2 by adding squared terms of transport infrastructure (business cycle) to examine whether relationship between transport infrastructure and transport carbon emissions (business cycle and transport carbon emissions) is an inverted U-shaped or not. It is argued that transportation infrastructure is positively linked with carbon emissions initially, but at latter stages of economic development, transportation infrastructure improves environmental quality by lower CO_2 emissions. This relationship between transportation infrastructure and transportation CO_2 emissions is termed as Transportation Kuznets curve (TKC). Similarly, we have also included squared term of business cycle i.e. economic activity to capture Environmental Kuznets curve (EKC). The EKC hypothesis indicates that economic growth increases carbon emissions initially, carbon emissions start to decline after threshold of real GDP per capita at latter stages of economic development. This inverted U-shaped relationship between economic growth and carbon emissions is termed as EKC hypothesis. The empirical equation to estimate Transportation and Environmental Kuznets curve is modelled as following:

$$\ln C_t = \alpha_0 + \alpha_1 \ln T_t + \alpha_2 \ln T_t^2 + \alpha_3 \ln Y_t + \alpha_4 \ln Y_t^2 + \alpha_5 \ln E_t + \alpha_6 \ln EP_t + \mu_i \tag{3}$$

The relationship between transportation infrastructure and carbon emissions is inverted-U shaped if $\alpha_1 > 0, \alpha_2 < 0$ otherwise U-shaped if $\alpha_1 < 0, \alpha_2 > 0$. If $\alpha_3 < 0, \alpha_4 > 0$ then association between economic growth and carbon emissions is U-shaped otherwise it is inverted-U shaped if $\alpha_3 > 0, \alpha_4 < 0$.

3.2. The Data Collection

The study employs monthly data covering the period of 2000M1-2017M12. We have collected data for transportation carbon emissions from United States (U.S.) Environmental Protection Agency. Transportation carbon emissions are comprised of emissions from passenger cars, light-duty trucks, sport utility vehicles, pickup trucks, minivans, freight trucks, commercial aircraft, ships, boats, and trains, pipelines and lubricants etc. Transportation energy consumption data is collected from U.S. Energy Information Administration and data is comprised of energy consumed by cars, motorcycles, light trucks, boats, airplanes, trucks, buses, trains, ships, jet airplanes, helicopters, government and private vehicle fleets etc. We have combed International Financial Statistics (CD-ROM, 2018) to collect data on industrial production index. Industrial production index in U.S. is based on production of business put together with industrial sector. Manufacturing contributes to total output by 78%. In manufacturing, contributors are such as: Chemicals (12%), food, drink and tobacco (11%), machinery (6%), fabricated metal products (6%), computer and electronic products (6%) and 6% is contributed by motor vehicles and parts. A 11% in manufacturing is contributed by Mining and quarrying and rest 11% is accounted by utilities. The data on passenger transportation services index, freight transportation services index and total transportation services index is collected from Economic Research Division, Federal Reserve Economic Data. The passenger transportation services index measures month-to-month variations in the production of services offered by the for-hire transportation industries. The freight transportation services index, accounts for variations occurring in freight shipments which is based on the amount received for freight carried by for-hire transportation industry. Finally, total transportation services index shows month-to-months variations in transportation services. The data on crude oil prices collected from Economic Research Division, Federal Reserve Economic Data.

4. Estimation Strategy

4.1. Bounds Testing Cointegration Approach

Existing applied economic literature provides various cointegration tests to examine that a cointegration relationship either exists or does not exist between macroeconomic variables. These cointegration tests are the Engle-Granger cointegration test developed by Engle and Granger (1987), the maximum likelihood cointegration test by Johansen and Juselius (1990) and the dynamic ordinary least square method by Stock and Watson, (1993). These cointegration tests require a unique integrating of the order of the variables. We are unable to examine cointegration between the variables if the variables are integrated at a mixed order of integration (i.e., I[0]/I[1]). This issue is solved by the bounds testing approach to cointegration introduced by Pesaran et al. (2001) termed as the Autoregressive Distributed Lag (ARDL) or bounds testing approach to cointegration. This approach is flexible for the order of integration of the variables if none of the variable are found stationary at I(2). The bounds testing approach performs better for small sample-size data. This test minimises the problem of serial correlation via Monte Carlo simulations, and this property is absent in traditional cointegration approaches. We can accommodate the information of break time by inserting a dummy variable in an unrestricted error correction model (UECM) version of the ARDL bounds testing approach. Due to the appeal of these properties, we prefer the bounds testing approach for examining the cointegration between the variables. The empirical equations of the UECM are as follows:

$$\begin{aligned}\Delta \ln C_t &= \beta_1 + \beta_T T + \beta_Y \ln Y_{t-1} + \beta_E \ln E_{t-1} + \beta_{EP} \ln EP_{t-1} + \beta_T \ln T_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln C_{t-i} \\ &\quad + \sum_{j=0}^{q} B_j \Delta \ln Y_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln EP_{t-l} + \sum_{m=0}^{p} \beta_m \Delta \ln Y_{t-m} + \mu_t\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta \ln Y_t &= \beta_1 + \beta_T T + \beta_Y \ln Y_{t-1} + \beta_E \ln E_{t-1} + \beta_{EP} \ln EP_{t-1} + \beta_T \ln T_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln Y_{t-i} \\ &\quad + \sum_{j=0}^{q} B_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln E_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln EP_{t-l} + \sum_{m=0}^{p} \beta_m \Delta \ln T_{t-m} + \mu_t\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta \ln E_t = {} & \beta_1 + \beta_T T + \beta_Y \ln Y_{t-1} + \beta_E \ln E_{t-1} + \beta_{EP} \ln EP_{t-1} + \beta_T \ln T_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln E_{t-i} \\ & + \sum_{j=0}^{q} B_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln EP_{t-l} + \sum_{m=0}^{p} \beta_m \Delta \ln T_{t-m} + \mu_t\end{aligned} \qquad (6)$$

$$\begin{aligned}\Delta \ln EP_t = {} & \beta_1 + \beta_T T + \beta_Y \ln Y_{t-1} + \beta_E \ln E_{t-1} + \beta_{EP} \ln EP_{t-1} + \beta_T \ln T_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln EP_{t-i} \\ & + \sum_{j=0}^{q} B_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln E_{t-l} + \sum_{m=0}^{p} \beta_m \Delta \ln T_{t-m} + \mu_t\end{aligned} \qquad (7)$$

$$\begin{aligned}\Delta \ln T_t = {} & \beta_1 + \beta_T T + \beta_Y \ln Y_{t-1} + \beta_E \ln E_{t-1} + \beta_{EP} \ln EP_{t-1} + \beta_T \ln T_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln T_{t-i} \\ & + \sum_{j=0}^{q} B_j \Delta \ln C_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln Y_{t-k} + \sum_{l=0}^{s} \beta_l \Delta \ln E_{t-l} + \sum_{m=0}^{p} \beta_m \Delta \ln EP_{t-m} + \mu_t\end{aligned} \qquad (8)$$

where Δ and μ_t are the difference operator and residual term, respectively. The Akaike information criteria (AIC) is used for appropriate lag length. The ARDL F-statistic is sensitive with lag order. The inappropriate lag order definitely provides a biased ARDL F-statistic, which presents an ambiguous conclusion regarding cointegration between the variables. The ARDL F-statistic basically shows the joint significance of the estimates of lagged variables at level and helps in making a decision that either cointegration is present or not (Peseran et al. 2001). The null hypothesis containing no cointegration between the variables is $H_0 : \beta_C = \beta_Y = \beta_E = \beta_{EP} = \beta_T = 0$, and the alternate hypothesis containing cointegration between the series is $H_0 : \beta_C \neq \beta_Y \neq \beta_{EP} \neq \beta_E \neq \beta_T \neq 0$ following equation-4. We compare our calculated ARDL F-statistic with the lower and upper critical bounds generated by Pesaran et al. (2001). The decision is in favour of cointegration if the upper bound is less than the calculated F-statistic. We claim no cointegration if the calculated F-statistic does not exceed the lower bound. If the calculated F-statistic is between the lower and upper critical bounds, then the decision is inconclusive. We also conduct the stability of the bounds testing parameters by applying CUSUM and CUSUMsq tests.

The long-run impact of business cycle, crude oil prices, transport energy consumption and transport infrastructure on transport carbon emissions can be examined by using the model as follows:

$$\ln C_t = \theta_0 + \theta_1 \ln Y_t + \theta_2 \ln EP_t + \theta_3 \ln E_t + \theta_4 \ln T_t + \mu_i \qquad (9)$$

where $\theta_0 = -\alpha_1 / \alpha_y, \theta_1 = -\alpha_{EP} / \alpha_1, \theta_2 = -\alpha_E / \alpha_1, \theta_3 = -\alpha_I / \alpha_1, \theta_4 = -\alpha_T / \alpha_1$, and μ_t is an error term. For the short run, the impact of business cycle, crude oil prices, transport energy consumption and transport infrastructure on transport carbon emissions can be investigated by applying the error correction model (ECM) as given below:

$$\Delta \ln C_t = \varphi_{01} + \sum_{i=1}^{l} \varphi_{11} \Delta \ln Y_{t-i} + \sum_{j=0}^{m} \varphi_{22} \Delta \ln EP_{t-j} + \sum_{k=0}^{n} \varphi_{33} \Delta \ln E_{t-k} + \sum_{r=0}^{o} \varphi_{44} \Delta \ln T_{t-r} + \eta ECM_{t-1} + \mu_i \qquad (10)$$

,

where Δ is the difference operator and η is the coefficient of the lagged error term, which indicates the speed of adjustment from a short-run equilibrium path to a long-run equilibrium path.

4.2. Vector Error Correction Granger Causality Test

The Vector Error Correction Model (VECM) is used to unveil the causal linkage between the variables. Granger, (1969) argued that if cointegration is present and the variables are stationary at the first difference, then causality must be present between the variables at least from one direction. The empirical equation of the VECM Granger causality is modelled as follows:

$$(1-L)\begin{bmatrix} \ln C_t \\ \ln Y_t \\ \ln EP_t \\ \ln E_t \\ \ln T_t \end{bmatrix} = \begin{bmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \\ a_5 \end{bmatrix} + \sum_{i=1}^{p}(1-L)\begin{bmatrix} b_{11i}b_{12i}b_{13i}b_{14i}b_{15i} \\ b_{21i}b_{22i}b_{23i}b_{24i}b_{25i} \\ b_{31i}b_{32i}b_{33i}b_{34i}b_{35i} \\ b_{41i}b_{42i}b_{43i}b_{44i}b_{45i} \\ b_{51i}b_{52i}b_{53i}b_{54i}b_{55i} \end{bmatrix} \times \begin{bmatrix} \ln C_{t-1} \\ \ln Y_{t-1} \\ \ln EP_{t-1} \\ \ln E_{t-1} \\ \ln T_{t-1} \end{bmatrix} + \begin{bmatrix} \alpha \\ \beta \\ \delta \\ \phi \\ \varphi \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \\ \varepsilon_{5t} \end{bmatrix} \quad (11)$$

where $(1-L)$ is the difference operator, and ECT_{t-1} is the lagged error term. The error terms are shown by $\varepsilon_{1t}, \varepsilon_{2t}, \varepsilon_{3t}, \varepsilon_{4t}$ and ε_{5t}. The significance of F-statistic shows the presence of a short-run causal relationship using the first differences of the series in the model. The existence of a long-run causal relationship is shown by the significance of ECT_{t-1}. Transport carbon emissions is a Granger cause of business cycle if $b_{12,i} \neq 0 \forall_i$, and business cycle is a Granger cause of transport carbon emissions if $b_{21,i} \neq 0 \forall_i$.

5. Empirical Findings and their Discussion

Table-1 shows the descriptive statistics and pair-wise correlations between the variables. We find that volatility in business cycle is less than volatility occurs in transportation carbon (CO_2) emissions. Crude oil prices have high volatility compared to volatility in transportation energy consumption. Volatility in passenger transportation services is higher than volatility in freight transportation and overall transportation services. In correlation analysis, we find positive correlations between business cycle (transportation energy) and transportation CO_2 emissions. Crude oil prices are inversely linked with transportation CO_2 emissions. Freight, passenger and overall transportation services are negatively correlated with transportation CO_2 emissions. The negative correlation exists between crude oil prices and business cycle. Transportation energy consumption, freight, passenger and overall transportation services are positively correlated with economic activity. The negative association is found between transportation energy consumption and crude oil prices. The positive correlation of freight, passengers and overall transportation services with crude oil prices is noted. Freight (passenger) and overall transportation services are negatively (positively) correlated with transportation energy consumption. A positive correlation exists between freight, passenger and overall transportation services.

Table-1: Descriptive Statistics and Pair-wise Correlation Analysis

Variables	$\ln C_t$	$\ln Y_t$	$\ln EP_t$	$\ln E_t$	$\ln F_t$	$\ln P_t$	$\ln T_t$
Mean	-0.7315	4.5924	5.2307	5.1495	4.7052	4.7083	4.7074
Median	-0.7679	4.6017	5.2965	5.1778	4.7077	4.7265	4.7140
Maximum	-0.6579	4.6692	5.6026	5.2426	4.8751	4.8489	4.8590
Minimum	-0.8020	4.4666	4.7318	5.0554	4.5507	4.4200	4.5422
Std. Dev.	0.0567	0.0505	0.2437	0.0602	0.0762	0.0886	0.0761
Skewness	0.1350	-0.3587	-0.5549	-0.1249	0.0723	-0.6678	-0.0078
Kurtosis	1.1819	2.0371	2.0410	1.4158	2.2778	2.8670	2.1612
Sum	-158.024	991.964	1129.831	1112.312	1016.343	1016.998	1016.817
Sum Sq. Dev.	0.6925	0.5493	12.773	0.7812	1.2502	1.6886	1.2459
$\ln C_t$	1.0000						
$\ln Y_t$	0.3089	1.0000					
$\ln EP_t$	-0.0024	-0.1210	1.0000				
$\ln E_t$	0.3627	0.1713	-0.0670	1.0000			
$\ln F_t$	-0.1334	0.3216	0.0849	-0.0995	1.0000		
$\ln P_t$	-0.3010	0.1347	0.0257	0.0250	0.1610	1.0000	
$\ln T_t$	-0.2918	0.3262	0.0856	-0.07713	0.8664	0.6298	1.0000

In order to test the unit root properties of transportation CO_2 emissions, business cycle, transportation energy consumption, crude oil prices, freight transportation services, passenger transportation services and overall transportation services, we have applied ADF unit root test with and without structural breaks in the series. The results of traditional ADF unit root test are reported in Table-2. We find that transportation CO_2 emissions, business cycle, transportation energy consumption, crude oil prices, freight transportation services, passenger transportation services and overall transportation services contain unit root problem. All the variables are found stationary after 1st difference. The empirical results provided by ADF unit root test are ambiguous. The ADF unit root test is unable to accommodate information about structural breaks and may accept null hypothesis when it is false due to their weak explanatory power. This issue is solved by applying ADF developed by Kim and Perron (2009) accommodating information about single unknown structural break in the series. The results are reported in Table-2. We find that all the variables are found non-stationary in the presence of structural breaks in the series. These breaks are $2005M_{11}$, $2010M_{11}$, $2014M_{07}$, $2009M_{02}$, $2008M_{07}$, $2006M_{11}$ and $2008M_{07}$ for CO_2 emissions, business cycle, crude oil prices, transportation energy consumption, freight transportation services, passenger transportation services and overall transportation services. These structural breaks are outcomes related in part to reforms implemented by US government to control carbon emissions in transport sector. For instance, on August 2005, the USA President signed into law the Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU). This law provided for certain funding for highways, highway safety, and public transportation totaling \$244.1 billion. This represented the largest surface transportation investment in the country’s history to meet the Nation’s future challenges. It addressed crucial issues such as improving safety, reducing traffic overcrowding, improving efficiency in freight movement, increasing intermodal connectivity, and protecting the environment. For the latter, it called for retaining and increasing funding for existing environmental programs, and on adding new environmental programs. It also incorporated changes intended at improving and streamlining the environmental process for transportation projects. We find all the variables stationary after 1st difference.

Table-2: Unit Root Analysis

Variable	ADF Test at Level		Kim-Perron ADF Test at Level			Decision
	T- Statistic	P. Value	T- Statistic	P. Value	Break Year	
$\ln C_t$	-1.7911	0.7050	-2.8437	0.9794	2005M$_{11}$	Unit Root
$\ln Y_t$	-1.9893	0.6034	-3.3895	0.4712	2010M$_{11}$	Unit Root
$\ln EP_t$	-1.8441	0.6797	-3.3891	0.7556	2014M$_{07}$	Unit Root
$\ln E_t$	-2.3696	0.3944	-3.1157	0.9432	2009M$_{02}$	Unit Root
$\ln F_t$	-1.8461	0.6787	-4.3436	0.3141	2008M$_{07}$	Unit Root
$\ln P_t$	-2.6326	0.2663	-4.0818	0.1469	2006M$_{11}$	Unit Root
$\ln T_t$	-2.1430	0.5184	-4.7766	0.1310	2008M$_{07}$	Unit Root
$\Delta \ln C_t$	-5.8921*	0.0000	-5.4506*	0.0000	2009M$_{01}$	Stationary
$\Delta \ln Y_t$	-3.7632**	0.0203	-5.8687*	0.0000	2009M$_{01}$	Stationary
$\Delta \ln EP_t$	-10.5448*	0.0000	-12.0136*	0.0000	2008M$_{11}$	Stationary
$\Delta \ln E_t$	-4.6431*	0.0011	-6.2600*	0.0000	2010M$_{01}$	Stationary
$\Delta \ln F_t$	-7.7729*	0.0000	-16.7061*	0.0000	2009M$_{04}$	Stationary
$\Delta \ln P_t$	-17.7933*	0.0000	-27.6125*	0.0000	2001M$_{09}$	Stationary
$\Delta \ln T_t$	-17.6432*	0.0000	-18.6787*	0.0000	2001M$_{09}$	Stationary
Note: * and ** show significance at 1% and 5% levels respectively.						

The unique integrating order of the variables inclines for applying bounds testing approach to cointegration for examining long run relationship between the variables. This cointegration test is applicable if we have variables integrated at I(1) or I(0) or I(1) / I(0). We need an information for appropriate lag length selection before proceeding to bounds testing approach to cointegration. The ARDL-F statistic is sensitive with lag length selection. In doing so, we used Akaike Information Criteria (AIC) for choosing appropriate lag length of the variables. The lag length selection is reported in Table-3 (second column 2). The results of computed ARDL F-statistics are reported in Table-3. We find that we may reject null hypothesis of no cointegration as CO$_2$ emissions, business cycle, transportation energy consumption, and passenger transportation services are treated as dependent variables. The computed ARDL F-statistics are more than upper critical bounds at 1% and 5% levels significantly. This confirms the presence of four cointegrating vectors. We accept null hypothesis of no cointegration as ARDL F-statistic is less than lower critical bound when we used crude oil prices as dependent variable. We may conclude that CO$_2$ emissions, business cycle, crude oil prices, transportation energy consumption, and passenger transportation services have cointegration for US economy over the period of 2000$_{M1}$-2017$_{M12}$. The results are similar we used freight transportation services and overall transportation services as measures of transportation infrastructure. This implies the reliability and consistency of cointegration analysis.

Table-3: ARDL Cointegration Analysis

Bounds Testing Approach to Cointegration				Diagnostic tests			
Estimated Models	Lag Length	Break Year	F-statistic	χ^2_{Normal}	χ^2_{serial}	χ^2_{Hetero}	$\chi^2_{\text{Re}msay}$
$C_t = f(P_t, Y_t, E_t, EP_t)$	2, 2, 2, 2, 1	2005M$_{11}$	8.801*	0.4582	0.2324	0.5803	0.5033
$P_t = f(C_t, Y_t, E_t, EP_t)$	2, 2, 2, 1, 2	2006M$_{11}$	3.985**	0.4080	0.2121	0.5606	0.5236
$Y_t = f(C_t, P_t, E_t, EP_t)$	2, 2, 1, 2, 2	2010M$_{11}$	8.789*	0.4284	0.2425	0.5200	0.5031
$E_t = f(C_t, Y_t, P_t, EP_t)$	2, 2, 1, 1, 1	2009M$_{02}$	13.572*	0.3981	0.2027	0.5006	0.4937
$EP_t = f(C_t, Y_t, E_t, P_t)$	2, 2, 2, 1, 2	2014M$_{07}$	2.472	0.3902	0.2001	0.5062	0.5206
$C_t = f(F_t, Y_t, E_t, EP_t)$	2, 2, 2, 2, 1	2005M$_{11}$	11.440*	0.3781	0.2011	0.7584	0.3846
$F_t = f(C_t, Y_t, E_t, EP_t)$	2, 2, 2, 1, 2	2008M$_{07}$	4.404*	0.1409	0.9669	0.7686	0.3456
$Y_t = f(C_t, F_t, E_t, EP_t)$	2, 2, 1, 2, 2	2010M$_{11}$	6.391*	0.7313	0.9703	0.3677	0.7523
$E_t = f(C_t, Y_t, F_t, EP_t)$	2, 2, 1, 1, 1	2009M$_{02}$	14.637*	0.7417	0.6713	0.3407	0.7003
$EP_t = f(C_t, Y_t, E_t, F_t)$	2, 2, 2, 1, 2	2014M$_{07}$	1.875	0.4567	0.3457	0.9871	0.1765
$C_t = f(T_t, Y_t, E_t, EP_t)$	2, 2, 2, 2, 1	2005M$_{11}$	10.095*	0.3456	0.9876	0.3456	0.9845
$T_t = f(C_t, Y_t, E_t, EP_t)$	2, 2, 2, 1, 2	2008M$_{07}$	11.987*	0.3765	0.8965	0.2809	0.7984
$Y_t = f(C_t, T_t, E_t, EP_t)$	2, 2, 1, 2, 2	2010M$_{11}$	6.242*	0.4560	0.7869	0.2345	0.8919
$E_t = f(C_t, Y_t, T_t, EP_t)$	2, 2, 1, 1, 1	2009M$_{02}$	14.693*	0.4478	0.6537	0.2556	0.7839
$EP_t = f(C_t, Y_t, E_t, T_t)$	2, 2, 2, 1, 2	2014M$_{07}$	1.003	0.3790	0.6378	0.2409	0.7905
$C_t = f(P_t, P_t^2, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2005M$_{11}$	8.711*	0.4210	0.2120	0.5730	0.5102
$P_t = f(C_t, P_t^2, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2006M$_{11}$	4.015**	0.3960	0.2001	0.5589	0.5106
$P_t^2 = f(C_t, P_t, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2006M$_{11}$	4.205**	0.4006	0.2109	0.5409	0.5300
$Y_t = f(C_t, P_t, P_t^2, Y_t^2, EP_t, E_t)$	2, 2, 1, 1, 2, 2, 2	2010M$_{11}$	8.099*	0.4044	0.2395	0.5109	0.5009
$Y_t^2 = f(C_t, P_t, P_t^2, Y_t, EP_t, E_t)$	2, 2, 1, 1, 2, 2, 2	2010M$_{11}$	7.919*	0.4142	0.2305	0.5200	0.5100
$EP_t = f(C_t, P_t, P_t^2, Y_t, Y_t^2, E_t)$	2, 2, 2, 2, 2, 1, 2	2014M$_{07}$	2.078	0.4489	0.3050	1.0801	0.2006
$E_t = f(C_t, P_t, P_t^2, Y_t, Y_t^2, EP_t)$	2, 2, 2, 1, 1, 1, 1	2009M$_{02}$	10.075*	0.4004	0.2121	0.5161	0.4887
$C_t = f(F_t, F_t^2, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2005M$_{11}$	8.661*	0.4240	0.2202	0.5793	0.5200
$F_t = f(C_t, F_t^2, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2006M$_{11}$	3.895**	0.3985	0.2200	0.5495	0.5015
$F_t^2 = f(C_t, F_t, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2006M$_{11}$	4.035**	0.4015	0.2189	0.5409	0.5205
$Y_t = f(C_t, F_t, F_t^2, Y_t^2, EP_t, E_t)$	2, 2, 1, 1, 2, 2, 2	2010M$_{11}$	7.349*	0.4262	0.2402	0.5187	0.4987
$Y_t^2 = f(C_t, F_t, F_t^2, Y_t, EP_t, E_t)$	2, 2, 1, 1, 2, 2, 2	2010M$_{11}$	7.819*	0.4029	0.2105	0.4980	0.4995
$EP_t = f(C_t, F_t, F_t^2, Y_t, Y_t^2, E_t)$	2, 2, 2, 2, 2, 1, 2	2014M$_{07}$	1.6908	0.4300	0.2949	0.8955	0.2142
$E_t = f(C_t, F_t, F_t^2, Y_t, Y_t^2, EP_t)$	2, 2, 2, 1, 1, 1, 1	2009M$_{02}$	9.015*	0.4165	0.2220	0.5363	0.4989
$C_t = f(T_t, T_t^2, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2005M$_{11}$	8.769*	0.4302	0.2004	0.5679	0.5113
$T_t = f(C_t, T_t^2, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2006M$_{11}$	4.045**	0.3800	0.1990	0.5584	0.5031
$T_t^2 = f(C_t, T_t, Y_t, Y_t^2, EP_t, E_t)$	2, 2, 2, 2, 2, 1, 2	2006M$_{11}$	4.045**	0.3684	0.2085	0.5494	0.5101
$Y_t = f(C_t, T_t, T_t^2, Y_t^2, EP_t, E_t)$	2, 2, 1, 1, 2, 2, 2	2010M$_{11}$	8.209*	0.3994	0.2298	0.5089	0.4980
$Y_t^2 = f(C_t, T_t, T_t^2, Y_t, EP_t, E_t)$	2, 2, 1, 1, 2, 2, 2	2010M$_{11}$	7.729*	0.3992	0.2285	0.5190	0.5109
$EP_t = f(C_t, T_t, T_t^2, Y_t, Y_t^2, E_t)$	2, 2, 2, 2, 2, 1, 2	2014M$_{07}$	1.789	0.4309	0.3154	1.1811	0.2161

$E_t = f(C_t, T_t, T_t^2, Y_t, Y_t^2, EP_t)$	2, 2, 2, 1, 1, 1, 1	2009M$_{02}$	9.705*	0.3984	0.2002	0.5090	0.4797

Note: The asterisks * and ** denote significance at the 1% and 5% levels, respectively, based on the critical values generated by the bootstrap procedure. The optimal lag length is determined by AIC. F_{PSS} is the F-statistic based on the asymptotic critical bounds, which is generated from bootstrap method. T_{DV} is the t-statistic for the dependent variable, T_{IV} is the t-statistic for independent variables, LM is the Langrage Multiplier test and JB is the Jarque-Bera test.

The long run effect of transport infrastructure, business cycle, transport energy consumption and crude oil prices on transport carbon emissions is reported in Table-4. We have used three proxies for transport infrastructure i.e. Passenger Transportation Services index, Freight Transportation Services index and Overall Transportation Services index. By using passenger transportation services index as measure of transportation infrastructure, we find that passenger transportation services have negative effect on transportation carbon emissions. It shows that a 1% increase in passenger transportation services reduces transportation carbon emissions by 0.1961%. Contrarily, Darido et al. (2014) reported that rise in urban transpiration has positive effect on carbon emissions in Chinese cities. The relationship between business cycle and transportation CO_2 emissions is positive and significant. It is noted that a 0.5004-0.5710% increase in transportation carbon emissions is led by 1% increase in business cycle. This finding is not consistent with the results of Alege et al. (2017) in which they found the existence of counter-cyclical relationship between carbon emissions and total output fluctuation for the Nigerian economy. Similarly, Al-Mulali and Ozturk, (2015) also reported the positive and significant effect of industrial production on carbon emissions using data of MENA region. Transport energy consumption affects transport carbon emissions significantly. We find that a 1% increase in transportation carbon emissions is led by 0.4982-0.5699% increase in transport energy consumption. This further implies transport energy consumption is not beneficial for environmental health of U.S. economy. Moreover, this finding is a sign of atmospheric pollution problems in U.S. However, this empirical finding is consistent with Kenworthy, (2003) who reported that transportation energy has positive and significant effect on carbon emissions using global city-level data. The similar finding is also observed in the recent study of Song et al. (2016a) where they find that excessive energy consumption in the transportation system of Chinese regions adds in atmospheric pollution. Subsequently, Song et al. (2016b) find the mixed findings across eastern and western regions of China where eastern region produces higher environmental efficiency due to railway transport and western region also produces lower environmental efficiency. Crude oil prices are negatively and significantly linked with carbon emissions in transport sector. Keeping other things constant, a 1% increase in energy prices leads transportation carbon emissions by 0.0405-0.1573%. Similarly, freight transportation services index (overall transportation services index) has negative and significant effect on transportation carbon emissions. This implies that improvement in transport infrastructure declines carbon emissions in transport sector of the US economy. This is the case with the US economy where the federal government has recently suggested for the usage of technology in transport sector in order to bring fuel efficiency and fully recyclable transport vehicles. This may be helping US economy in the improvement of environmental quality.

The linear and squared terms of transport infrastructure (passenger transportation services index, freight transportation services index and overall transportation services index) is positively and negatively linked with transport CO_2 emissions. It implies that carbon emissions in transport sector are accompanied with transport infrastructure initially and improvements in transport infrastructure up to certain decline CO_2 emissions. This inverted U-shaped relationship between transport infrastructure and carbon emissions is termed as

Transportation Kuznets Curve (TKC). In this line, our findings suggest that federal government should enhance long-run transport infrastructure in order to have sustainable environmental quality via reduction of carbon emissions. Similarly, Hassan and Nosheen (2019) reported the presence of railway Kuznets curve i.e. inverted U-shaped association between railway transportation services and N_2O (methane) emissions. Similarly, Jiang et al. (2019) also reported the validation of inverted U-shaped relationship between public transportation and carbon emissions using Chinese provincial data. The relationship between business cycle i.e. economic activity (linear and squared terms) and transportation carbon emissions is an inverted U-shaped. It shows that business cycle increases carbon emissions initially but after a threshold level, carbon emissions start to decline. This not only confirms the presence of environmental Kuznets curve (EKC) but also it is beneficial for the US economy in the long-run. The dummy variable indicating the implementation of The Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (SAFETEA-LU) has negative and significant effect on carbon emissions in transport sector. This reveals that implementation of SAFETEA-LU has improved environmental quality by lowering transportation carbon emissions. The empirical analysis of long run relationship shows absence of serial correlation, ARCH and white heteroscedasticity. The functional form of empirical models is well designed. The residual term is normally distributed confirmed by Jarque-Bera normality test which reveals that the hypothesis of misspecification cannot be rejected. The CUSUM and CUSUMsq tests also confirm the reliability of long run empirical analysis which indicated that the hypothesis of reliability cannot be rejected.

Table-4: Long Run Analysis

Dependent Variable: $\ln C_t$						
Variable	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	-5.1306*	-5. 9198*	-5.3918*	-31.9448*	-21.3867*	-31.4796*
$\ln P_t$	-0.1961*	….	….	5.6106*	….	….
$\ln P_t^2$	….	….	….	-0.6246*	….	….
$\ln F_t$	….	-0.0625**	….	….	17.1822*	….
$\ln F_t^2$	….	….	….	….	-1.8253*	….
$\ln T_t$	….	….	-0.1174*	….		16.3528*
$\ln T_t^2$	….	….	….	….		-1.7487*
$\ln Y_t$	0.5710	0.5004*	0.5492*	6.5286**	10.0253**	11.1220**
$\ln Y_t^2$	….	….	….	-0.6424**	-1.1422**	-1.1515**
$\ln E_t$	0.5699*	0.5947*	0.5757*	0.5134*	0.5318*	0.4982*
$\ln EP_t$	-0.0405*	-0.0468*	-0.0462*	-0.0692*	-0.0985*	-0.1573*
D_t	-0.0328*	-0.0497*	-0.0470*	-0.0209*	-0.0352*	-0.0360*
R^2	0.9575	0.9460	0.9481	0.9654	0.9649	0.9462
$adj-R^2$	0.9565	0.9447	0.9469	0.9642	0.9638	0.9446
F-Statistic	9.4805*	7.3279*	7.6834*	8.2908*	8.1910*	6.1267*
Stability Analysis						
Test	F-Statictic	P. Value	F-Statictic	P. Value		
χ^2_{Normal}	1.7723	2.0189	3.9604	3.7710	2.9656	3.4821
χ^2_{serial}	3.2619	2.7479	3.3662	2.7631	2.6675	2.9803
χ^2_{ARCH}	1.4913	3.0832	2.9430	1.1751	1.2401	1.7709

χ^2_{Hetero}	1.5464	1.0701	1.0290	3.9716	2.4330	2.4681
χ^2_{Ramsay}	2.7098	2.6444	2.0916	2.1946	2.2367	2.2446
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable
CUSUMsq	Stable	Stable	Stable	Stable	Stable	Stable
Note: CUSUM denotes cumulative sum and CUSUMsq shows the sumulative sum of square. The asterisks * and ** denote significance at the 1% and 5% levels, respectively.						

The short run empirical results are reported in Table-5. We find that transport infrastructure (passenger transport services, freight transport services and overall transport services) has negative but insignificant effect on carbon emissions in transport sector. Business cycle has positive and significant effect on transportation CO_2 emissions. In transportation sector, energy consumption and carbon emissions are negatively and significantly linked. It shows that transportation energy consumption lowers transport carbon emissions. Crude oil prices are negatively but insignificantly linked with transport CO_2 emissions. The linear and squared terms of passenger transportation services (freight transportation services and overall transportation services) have positive and negative (negative) effect on transportation carbon emissions but it is statistically insignificant. Similarly, the relationship between business cycle and transportation CO_2 emissions is inverted U-shaped presenting EKC phenomenon as we used freight transportation services as measure of transportation infrastructure. The effect dummy variable is negative and significant which implies that implementation of SAFETEA-LU declines transport carbon emissions. We find that estimate of lagged error correction term i.e. ECM_{t-1} is negative and statistically significant as we used passenger transportation services, freight transportation services and overall transportation services as measures of transportation infrastructure. This significance of ECM_{t-1} reveals the validation of established long run relationship between transportation carbon emissions and its determinants. The coefficient of ECM_{t-1} using overall transportation infrastructure (passenger transportation services) and freight transportation infrastructure as indicator of transportation are -0.0145 (-0.0268) and -0.0139 which are significant at 1% (1%) and 5% levels respectively. The negative coefficient of ECM_{t-1} shows the speed of adjustment from short-run towards long-run equilibrium path. We may conclude that any short run change in transportation carbon emissions is corrected by 2.68%, 1.39% and 1.45% for passenger transportation services, freight transportation services and overall transportation services measures of transportation infrastructure[7].

Table-5 also shows empirical results of diagnostic analysis. We find the absence of serial correlation in empirical models. All empirical models have normal distribution. There is no evidence of ARCH and white heteroscedasticity. The Ramsey Reset test confirms the well specification i.e. “the hypothesis of misspecification cannot be rejected” of all empirical models applied for empirical analysis. We have also applied CUSUM and CUSUMsq tests in order to examine the reliability of long run and short run estimates. The results show that CUSUM and CUSUMsq are stable i.e. “the hypothesis of stability cannot be rejected”. Based on empirical results of CUSUM and CUSUMsq reported in Table-4 and 5, we may conclude that short run as well as long run estimates are reliable and consistent.

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[7] The speed of adjustment for nonlinear models is 2.78%, 1.06% and 1.10% for passenger transportation services, freight transportation services and overall transportation services measures of transportation infrastructure.

Table-5: Short Run Analysis

Dependent Variable: $\Delta \ln C_t$						
Variable	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient	Coefficient
Constant	0.0004	0.0004	0.0004	0.0004	0.0008**	0.0005**
$\Delta \ln P_t$	-0.0028	….	….	-0.0015	….	….
$\Delta \ln P_t^2$	….	….	….	0.0109	….	….
$\Delta \ln F_t$	….	-0.0259	….	….	-0.0302**	….
$\Delta \ln F_t^2$	….	….	….	….	-0.7406	….
$\Delta \ln T_t$	….	….	-0.0232	….	….	-0.0298
$\Delta \ln T_t^2$	….	….	….	….	….	-0.4541
$\Delta \ln Y_t$	0.1351*	0.1390*	0.1320*	0.1247*	0.1165*	0.1163
$\Delta \ln Y_t^2$	….	….	….	-0.7304	-0.9555*	-1.0576
$\Delta \ln E_t$	-0.2854*	-0.2927*	-0.2916*	-0.2954*	-0.3033*	-0.2293*
$\Delta \ln EP_t$	-0.0043	-0.0048	-0.0049	-0.0051	-0.0062	-0.0055
D_t	-0.0014*	-0.0015*	-0.0015*	-0.0014*	-0.0014*	-0.0015*
ECM_{t-1}	-0.0268*	-0.0139**	-0.0145*	-0.0278**	-0.0106**	-0.0110**
R^2	0.2561	0.2612	0.2556	0.2571	0.2662	0.2599
$adj\text{–}R^2$	0.2347	0.2398	0.2341	0.2282	0.2377	0.2311
F-Statistic	11.9882*	12.2563*	11.9072*	8.9135*	9.3438	9.0441*
Stability Analysis						
Test	F-Statistic	F-Statistic	F-Statistic	F-Statistic	F-Statistic	F-Statistic
χ^2_{Normal}	2.2024	0.1546	0.1703	0.2012	0.1599	0.1708
χ^2_{serial}	2.4895	2.7409	1.4515	0.4408	0.4455	0.4587
χ^2_{ARCH}	0.3531	0.4890	0.3711	0.3513	0.6732	0.5665
χ^2_{Hetero}	1.0098	1.9138	1.7735	0.8805	0.2329	1.7902
χ^2_{Remsay}	0.9053	0.8431	0.7932	1.1505	1.0190	1.0946
CUSUM	Stable	Stable	Stable	Stable	Stable	Stable
CUSUMsq	Stable	Stable	Stable	Stable	Stable	Stable
Note: The asterisks * and ** denote significance at the 1% and 5% levels, respectively.						

In order to examine causal relationship between transportation carbon emissions and its determinants, we have applied the VECM Granger causality test. The results of VECM Granger causality approach are reported in Table-6. In long run, we note that transportation carbon emissions cause transportation infrastructure (passenger transportation services) and transportation infrastructure causes transportation carbon emissions in Granger sense. The relationship between business cycle and transportation CO_2 emissions is bidirectional i.e. feedback effect. Energy consumption causes carbon emissions and carbon emissions cause energy consumption in transport sector within VECM Granger causality framework. The unidirectional is noted running from crude oil prices to transportation carbon emissions. Transportation energy consumption is Granger cause of crude oil prices. The unidirectional causality is found running from crude oil prices to business cycle. Transportation infrastructure (passenger transportation services) is Granger caused by crude oil prices. The results are similar as freight transportation services and overall transportation services are used as measures of transportation infrastructure. In short run, the feedback effect exists between business cycle and transportation carbon emissions. Energy consumption Granger causes carbon emissions and carbon emissions Granger cause energy consumption in transport sector. Passenger transportation services are Granger caused by economic activity. The neutral effect is found between passenger transportation services and transportation CO_2 emissions. The results are similar as freight transportation services and overall transportation services are used as measures of transportation infrastructure.

Table-6: The VECM based Granger Causality Analysis

Variables	Direction of Causality						
	Short Run					Long Run	Break Year
	$\Delta\ln C_t$	$\Delta\ln P_t$	$\Delta\ln Y_t$	$\Delta\ln E_t$	$\Delta\ln EP_t$	ECT_{t-1}	
Passengers Transport Services Index							
$\Delta\ln C_t$	….	1.2937 [0.2793]	8.2891* [0.0003]	10.1857 [0.0001]*	0.0718 [0.9307]	-0.0399** (-2.5962)	2005M_{11}
$\Delta\ln P_t$	0.5567 [0.5740]	….	4.7466* [0.0099]	0.0788 [0.9242]	1.4025 [0.2484]	-0.1931** (-2.5027)	2006M_{11}
$\Delta\ln Y_t$	7.3681 [0.0000]*	1.8994 [0.1523]	….	0.6020 [0.5487]	1.3571 [0.2597]	-01466* (-5.4345)	2010M_{11}
$\Delta\ln E_t$	3.3639 [0.0365]**	0.9261 [0.3978]	1.9067 [0.1512]	….	0.1078 [0.8978]	-0.0293** (-2.2060)	2009M_{02}
$\Delta\ln EP_t$	0.7960 [0.4525]	1.4631 [0.2316]	0.2885 [0.7802]	0.0160 [0.9841]	….	-0.0521 (-1.3541)	2014M_{07}
Freight Transport Services Index							
	$\Delta\ln C_t$	$\Delta\ln F_t$	$\Delta\ln Y_t$	$\Delta\ln E_t$	$\Delta\ln EP_t$	ECM_{t-1}	Break Year
$\Delta\ln C_t$	….	1.2747 [0.2803]	8.8298* [0.0001]	12.0807 [0.0000]*	0.1072 [0.9007]	-0.0369** (-2.6248)	2005M_{11}
$\Delta\ln F_t$	0.6557 [0.5400]	….	6.7040* [0.0054]	0.1718 [0.8802]	1.3345 [0.2504]	-0.1701** (-2.8727)	2008M_{07}
$\Delta\ln Y_t$	8.8691 [0.0000]*	2.0904 [0.1513]	….	0.7900 [0.5389]	1.2571 [0.2601]	-01306* (-5.6047)	2010M_{11}
$\Delta\ln E_t$	3.7679 [0.0255]**	1.0201 [0.3848]	1.8887 [0.1517]	….	0.2876 [0.8870]	-0.0288** (-2.4640)	2009M_{02}
$\Delta\ln EP_t$	0.8004 [0.4523]	1.4361 [0.2408]	0.2980 [0.7810]	0.0270 [0.9749]	….	-0.0401 (-1.5461)	2014M_{07}
Overall Transport Services Index							
	$\Delta\ln C_t$	$\Delta\ln T_t$	$\Delta\ln Y_t$	$\Delta\ln E_t$	$\Delta\ln EP_t$	ECM_{t-1}	Break Year
$\Delta\ln C_t$	….	1.2773 [0.2789]	9.9891* [0.0001]	12.1050 [0.0000]*	0.1070 [0.9245]	-0.0401** (-2.6025)	2005M_{11}
$\Delta\ln T_t$	0.7067 [0.5345]	….	8.7489* [0.0004]	0.1628 [0.8810]	1.2949 [0.2504]	-0.1701** (-2.8727)	2008M_{07}
$\Delta\ln Y_t$	8.9987 [0.0000]*	1.8984 [0.1645]	….	0.8019 [0.5345]	1.2741 [0.2564]	-01134* (-5.6498)	2010M_{11}
$\Delta\ln E_t$	8.6091 [0.0001]*	1.1230 [0.3698]	2.1807 [0.1373]	….	0.2660 [0.8901]	-0.0209** (-2.5130)	2009M_{02}
$\Delta\ln EP_t$	0.8314 [0.4443]	1.4608 [0.2358]	0.3068 [0.7804]	0.1320 [0.9689]	….	-0.0356 (-1.3431)	2014M_{07}
Note: * and ** indicate the significance at 1% and 5% levels respectively. [] shows probability values. () shows t-statistic.							

6. Conclusion and Policy Implications

This paper investigated the validation of Transportation Kuznets Curve i.e. transport infrastructure and carbon emissions, and Environmental Kuznets Curve i.e. business cycle and carbon emissions by incorporation crude oil prices and transportation energy consumption into transportation carbon emissions' function for the U.S. economy using monthly data for the period of 2000_{M1}-2017_{M12}. In doing so, we have applied structural unit root test developed by Kim and Perron (2009) in order to test the unit root properties of the variables. The cointegration between variables in the presence of structural breaks investigated by applying the ARDL bounds testing approach. The causal relationship between transportation carbon emissions and its determinants is examined by employing the VECM Granger causality approach in the presence of structural breaks.

The empirical results confirm the presence of cointegration between the variables. Moreover, transportation infrastructure (passenger transportation services, freight transportation services and overall transportation services) improves environmental quality by lowering transportation CO_2 emissions. Business cycle and energy consumption boost CO_2 emissions in transport sector. Crude oil prices lower energy demand which in resulting, declines transportation carbon emissions. The linear and squared effects of transportation infrastructure on carbon emissions are positive and negative i.e. inverted U-shaped which confirms the presence of transportation Kuznets Curve. Similarly, business cycle and transportation CO_2 emissions are linked in an inverted U-shaped behavior which validates the existence of Environmental Kuznets Curve. The causality analysis reveals the presence of feedback effect between transportation infrastructure and carbon emissions. Business cycle i.e. economic activity causes carbon emissions and in resulting, carbon emissions cause business cycle i.e. bidirectional causality. The bidirectional causal relationship is found between energy consumption and carbon emissions in transport sector. Energy prices Granger cause transportation carbon emissions, transportation infrastructure, energy consumption and business cycle.

Our findings bear crucial policy implications for the U.S. economy facing environmental challenges coupled with unpredictable climate and global warming. It is noted that transportation infrastructure is found to be the main driver of the reduction of CO_2 emissions in transport sector for the U.S. economy. Since the people in U.S. are very much concerned about the health consequence of air pollution, therefore they often prefer the usage of electric vehicles and road walking. Further, this finding not only shows the greater role of transportation infrastructure in the improvement of environmental quality via reduction of CO_2 emissions in the transport sector but also it is a major segment of the U.S. economy.[8] Hence, we also suggest policy-makers of the U.S. economy to promote not only the quality of transport infrastructure but also need to implement the stringent pollution-reducing transport infrastructure policy in order to have higher economic growth along with achieving greater sustainable environmental quality in the long-run. However, the government in U.S. should monitor everyday usage of oil and also need to check frequently the pollution certificate of vehicles used by the people in their daily travelling. An immediate implication is that if such practice of pollution control is implemented to a greater extent, then carbon emissions resulting from transport infrastructure are expected to be minimized. So the lower carbon emissions imply better air quality which also improves life expectancy of people in the long-run. In addition, increased oil prices are also found to restrain the growth of transport sector

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[8] About 1 in 5 dollars in the U.S. is spent annually on transportation products and services, and 1 in 16 Americans is employed directly by this sector (and up to 1 in 7 jobs, including indirect employment) (see at https://www.aps.org/policy/reports/popa-reports/energy/transportation.cfm).

CO_2 emissions in U.S. Thus, both policy-makers and federal government in U.S. should also design a policy of increasing energy prices that will lower energy demand and subsequently it will improve environmental quality via reducing carbon emissions. These policies in U.S. would reduce transport sector CO_2 emissions, and thereby help improve environmental quality in the long-run. In such line, few studies also recommended introducing digitalized technology on the road[9] and railway transport (Ružinski et al. 2011, Khorheh et al. 2015, Song et al. 2016b, Jayaraman et al. 2019) that not only reduces pollution level but that will enable the U.S. economy to have a smooth journey towards greenery transportation which could be sufficiently enough to end the postponement of climate change and global warming problems. The study of Barisa and Roša (2015) and Velazquez et al. (2015) suggests that since sustainable transportation system is essential for carbon reduction, it is important for transportation stakeholders to include environmental education, renewable energy usage over fossil fuels as well as vehicle makers should also produce more energy efficient vehicles. They further suggest that both non-motorized and public transport modes are preferable to motorized and private transportation modes for the reduction of carbon emissions. However, we argue that the policy-makers in U.S. should take a lesson from these recommendations while formulating sustainable transportation policy in the long-run.

Finally, both business cycles and transport sector energy consumption are not beneficial for the U.S. economy as they are primarily found to be responsible for driving transport sector CO_2 emissions growth over the study horizon. Transport sector CO_2 emissions linked with business cycles are highly pro-cyclical, indicating that it increases during expansion and decreases during recession periods of the U.S. economy. This finding is also consistent with the result of Khan et al. (2016) for the U.S. economy. Hence both policy makers and federal government should try to control the magnitude of business cycles as well as to reduce the usage of energy in transport sector in order to minimize both the adverse effects of business cycles and environmental degradation on economic prosperity and climate change. Since, energy consumption in transport sector intensifies transport sector CO_2 emissions growth,[10] the U.S. government should implement stringent fuel economy standards as one of the regulatory instruments or should give preferential treatment to less carbon intensive fuels, such as compressed natural gas, bio fuels, electricity and renewable energy. We believe that if these policies are successful in implementing large-scale switching from gasoline, petrol and diesel to decarbonize fuels, natural gas, biofuels, and electricity, then the fuel mix effect would reduce energy consumption intensity, and thereby would also help reduction of transport sector CO_2 emissions growth in U.S.[11] Since, our study in the introduction section detects road transport as the main factor in the growth of transport sector CO_2 emissions, we would leave it for the future research to explore the driving factors for the growth of road transport sector carbon emissions in U.S. Eventually this would enable policy-makers to understand the underlying policy implications in relation to the growth of road transport sector carbon emissions.

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[9] Jayaraman et al. (2019) argued that one of the major driving factors to environmental pollution is road traffic. The heavy reliance on vehicle is also the major cause of road traffic. If digitalized technology is implemented, the severe traffic congestion during peak hours can be managed well. In doing this, there will be much relied to traffic congestion as well as to the health of environment.

[10] This may be because the U.S. transport sector is a major consumer of fossil fuels, both directly by motor vehicles burning gasoline, aircraft burning jet fuel and indirectly, by consuming electric power for urban mass transit, and thereby it increases carbon emissions. This further implies that all modes of transport that consume mainly petroleum based fuels contribute to air and water pollution of the environment irrespective of energy intensity of the U.S. economy.

[11] See the more details on the policy effectiveness in the study of Timilsina and Shrestha (2009b) for the case of Asian countries.

This study can be augmented by using city-level data to examine whether TKC is valid or not. In doing so, we can apply transportation carbon emissions function in traffic congestion cities i.e. 10 best and 10 worst cities and compare their empirical results for a comprehensive transportation policy for controlling carbon emissions to improve environmental quality in longer period of time. We can also apply transportation carbon emissions function at global-level within the panel framework. In addition, the life expectancy consequence of carbon emissions generated in each and every city of the U.S. economy and in case of other developed and developing countries could be empirically explored within a panel framework. Based on empirical results, we can offer suitable policy recommendations how developed and developing countries solve the issue of environmental quality by tackling transportation modes in modern way. Last but not least, transportation system and technology are also potential determinants of transportation carbon emissions while investigating the validation of Transportation Kuznets Curve.

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Appendix

Table-A1: Definition of Variables

Abbreviation	Variable	Definition	Data Source
C_t	Transportation Carbon Emissions	Transportation carbon emissions are comprised of emissions from passenger cars, light-duty trucks, sport utility vehicles, pickup trucks, minivans, freight trucks, commercial aircraft, ships, boats, and trains, pipelines and lubricants etc.	U.S. Energy Information Administration (https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions)
Y_t	Business Cycle	Industrial production index (covers real output for all facilities situated in the US manufacturing, mining, and electric, and gas utilities.	https://fred.stlouisfed.org/series/INDPRO/
EP_t	Energy Prices	Crude oil prices: West Texas Intermediate (WTI)	https://fred.stlouisfed.org
E_t	Transportation Energy Consumption	Transportation energy consumption comprised of energy consumed by cars, motorcycles, light trucks, boats, airplanes, trucks, buses, trains, ships, jet airplanes, helicopters, government and private vehicle fleets etc.	U.S. Energy Information Administration (https://www.eia.gov/energyexplained/?page=us_energy_transportation)
T_t	Transportation	Passenger transportation services index, freight transportation services index, overall transportation services index	https://fred.stlouisfed.org

Table-A2: VIF and Tolerance Analysis

Variables	Before Transformation		After Transformation	
	VIF	Tolerance	VIF	Tolerance
Transportation Carbon Emissions Function with Overall Transportation Services Index				
$\ln Y_t$	37988.08	0.0000	1.61	0.6227
$\ln Y_t^2$	38150.79	0.0000	1.02	0.9788
$\ln E_t$	2.24	0.4460	1.28	0.7795
$\ln EP_t$	2.00	0.4998	1.91	0.5234
$\ln TSI_t$	8.08	0.1238	1.00	1.0000
Transportation Carbon Emissions Function with Freight Transportation Services Index				
$\ln Y_t$	37034.30	0.0000	1.48	0.6757
$\ln Y_t^2$	37089.72	0.0000	1.02	0.9818
$\ln E_t$	2.25	0.4435	1.50	0.6666
$\ln EP_t$	1.94	0.5164	1.91	0.5234
$\ln FTSI_t$	6.29	0.1589	1.00	1.0000
Transportation Carbon Emissions Function with Passenger Transportation Services Index				
$\ln Y_t$	42066.85	0.0000	1.48	0.6757
$\ln Y_t^2$	42261.89	0.0000	1.02	0.9818
$\ln E_t$	1.75	0.5731	1.28	0.7795
$\ln EP_t$	3.09	0.3232	1.91	0.5234
$\ln PTSI_t$	6.33	0.1579	1.00	1.0000