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RESEARCH ARTICLE

A transport environmental Kuznets curve analysis for Malaysia: exploring the role of corruption

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Abstract
Validity of the environmental Kuznets curve (EKC) hypothesis is consistently and widely debated among economists and environmentalists alike throughout time. In Malaysia, transport is one of the "dirtiest" sectors; it intensively consumes energy in powering engines by using fossil fuels and poses significant threats to environmental quality. Therefore, this study attempted an examination into the impact of corruption on transport carbon dioxide (CO_2) emissions. By adopting the fully modified ordinary least squares, canonical cointegrating regression, and dynamic ordinary least squares in performing long-run estimations, the results obtained based on the annual data spanning from 1990 to 2017 yielded various notable findings. First, more corruption would be attributable towards increased transport CO_2 emissions. Second, a monotonic increment of transport CO_2 emission was seen with higher economic growth and thus invalidated the presence of EKC. Overall, this study suggests that Malaysia has yet to reach the level of economic growth synonymous with transport CO_2 emission reduction due to the lack of high technology usage in the current system implemented. Therefore, this study could position policy recommendations of use to the Malaysian authorities in designing the appropriate economic and environmental policies, particularly for the transport sector.

Keywords Environmental Kuznets curve hypothesis · Carbon dioxide emissions · Transport sector · Corruption · Malaysia

Introduction

The transport sector plays an important role in ensuring a favourable socioeconomic development, particularly in developing countries such as Malaysia. In a globalised economy, its economic activities and opportunities are highly associated with the mobility of people and goods. In other words, a well-developed transport system is closely linked to a high level of economic development, which can be reflected in the increasing level of output, employment opportunities, and income. However, the economic opportunities and benefits from the transport sector are often derived at the expense of environmental quality due to combustion of petroleum-based products, including gasoline. Among all the economic sectors, transport is one of the fastest-growing contributors to global CO_2 emissions. Currently, this particular segment accounts for 29% of global total energy consumption and 24% of worldwide CO_2 emissions (Solaymani 2019). Such numbers are attributable to most modes of transportation that are still reliant on fossil fuels, except for train in which electricity is commonly used. Meanwhile, land transport, in particular, contributes the most proportionally to global transport energy growth and the subsequently increased CO_2 emissions, typically due to light-duty vehicle including cars (World Health Organization 2019).

In recent decades, the growth of Malaysian economy has resulted in a tremendous rise in car ownership. Statistics from the Malaysian Institute of Road Safety Research (2013) has shown that new passenger cars and goods vehicles travel

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approximately 24,000 and 70,000 km per year, respectively. Regarding the different types of transport mode, road transport has contributed to 85.2% of the total transportation emissions, wherein about 59% of the road emissions come from car usage (Briggs and Leong 2016). Besides, the Malaysian Automotive Association (2018) reported that the number of vehicles registered reached a total of 598,714 in 2018, whereby 522,392 were logged as passenger cars.

Furthermore, the continuous and robust economic developments seen in the country have led to a rapid increase in total energy demand in recent years (Go et al. 2020). Correspondingly, greenhouse gas (GHG) emissions also presented an upward trend as evidenced by CO_2 emissions recorded at 8.03 metric tonnes per capita in 2014 (World Bank 2019). Currently, Malaysia is planning to slash its GHG emission intensity by 45% based on the emissions intensity recorded in 2005, which is to be accomplished by year 2030. To achieve this target, the attention should be focused on the transport sector due to its role in causing approximately 35% of the total energy consumption in the country, while the total CO_2 emissions reach about 50 million metric tonnes annually. Besides, Malaysia is also aiming to reduce its CO_2 intensity per GDP by 45% in 2030 in parallel to the CO_2 intensity per GDP recorded in 2005. Therefore, this underlines the local government's need to prioritise emission reduction in the transport sector.

In general, the industry involving the construction of transport infrastructure has been consistently ranked as one of the most corrupt industries worldwide. In the context of Malaysia, such industry is closely intertwined with the government, thereby rendering corruption a morbid plague into the transport sector. This is typically seen by the drawing away of funds allocated for curbing transport CO_2 problems to private hands via bribery. As a result, it leads to undesirable practices, such as the development of harmful environmental policies and misallocation of environmental resources (Winbourne 2002). For example, bribery is a practice highly prevalent in the issuance of driving licences in the country. Similarly, corrupted officials employed in public services tend to pursue their personal interests instead of policy goals, which can affect the implementation and compliance of environmental laws (Lewis 2007; Callen and Long 2015).

Therefore, this study looks into the facets of corruption, which has yet to be researched, particularly in the case of Malaysia. Does corruption matter in shaping the transport carbon dioxide (CO_2) emission landscape? Is the transport environmental Kuznets curve (EKC) hypothesis closely related to corruption? Addressing these questions should be on the to-do list of Malaysian economists and environmentalists due to the transport sector's notoriety as one of the dirtiest sectors. To answer the above-addressed questions, two objectives are laid out accordingly. First, the impact of corruption on CO_2 emissions in the Malaysian transport sector for the period spanning from 1990 to 2017 is examined. Second, the EKC hypothesis is validated in the presence of corruption on environmental degradation in the context of the Malaysian transport sector.

To accommodate any structural changes in the cointegrating regressors, attempts are made to apply the fully modified ordinary least squares (Phillips and Hansen 1990), canonical cointegrating regression (Park 1992), and dynamic ordinary least squares (Stock and Watson 1993). The merits of these estimation techniques include allowing the inclusion of variables integrated with higher orders and solving the problem of simultaneity among the regressors. By looking at a single equation separately in small samples, these techniques are asymptotically efficient as alternative long-run estimators, including those proposed by Johansen (1988) and Phillips and Hansen (1990).

This study is primarily motivated by the fact that a limited amount of literature is available and offering in-depth insights for a single country in analysing the EKC hypothesis in the presence of corruption. Henceforth, it contributes to the existing body of knowledge in two important ways by combining the ideas positioned by Masron and Subramaniam (2018) and Liu et al. (2020) towards reinvestigating the impact of corruption in the relationship between pollution and growth. First, most studies conducted about the environmental consequences of corruption are generally based on panel data. For instance, Masron and Subramaniam (2018) have targeted 64 developing countries with data sourced for the period between 2005 and 2013, thus demonstrating that countries with a high level of corruption tend to be polluted. Meanwhile, Ozturk et al. (2019) have indicated that an increased corruption control from 2000 through 2017 was highly important for 60 countries from all income groups to enhance energy efficiency.

In line with the above, Liu et al. (2020) have performed panel analysis by considering five specific countries with high CO_2 emissions, wherein the results reveal that political, economic, and institutional governance enhance environmental quality. Nevertheless, these panel study findings provide merely a general understanding of the relationship among the assessed variables. In the case of developing countries, governmental institutions are less effective in controlling pollution (López and Mitra 2000). Typically, this leads to the tendency of corrupted officials to pursue their personal interests instead of specified policy goals, thereby further affecting the implementation and compliance of environmental laws (Fredriksson et al. 2003; Lewis 2007; Callen and Long 2015). Hence, protecting the environment via the implementation of better policies is associated with quality governance as a key driver for energy efficiency (Hosseini and Kaneko 2013; Talbi 2017; Apergis and Garćıa 2019). Different from previous studies, our study investigates the impact of corruption on pollution in a single country, i.e. Malaysia.

Second, specific works have conducted assessments in the context of Malaysia, wherein Chandran and Tang (2013) have applied CO_2 emissions per capita for the period from 1971 to 2008, while Azlina et al. (2014) use the quantity of CO_2 emission per capita for the period from 1975 to 2011. To the best of our knowledge, the present study is the first attempt towards exploring the implications of transport EKC in the country in the presence of corruption. Therefore, the focus is placed on transport CO_2 emission as an indicator of environmental degradation so as to generate new insights into the ongoing discussion of whether or not the nexus between environment-economic developments is in support of the EKC hypothesis, specifically in the context of the Malaysian transport sector.

Henceforth, this study can be seen as a response to earlier and limited studies by which it concentrates on corruption and its implication for the income-pollution nexus in Malaysia. In particular, such a single-country study may allow issues associated with cross-country studies to be eliminated. Besides, the works underlining the context of Malaysia are rather limited in detailing the trend of increasing GHG emission across the domestic transport sector. Therefore, this work will inevitably shed some light on the role of governance towards reducing the local transport CO_2 emissions, wherein it may be reasonable for one's expectation that an increased degree of national corruption is likely to worsen its environmental degradation. Additionally, Malaysia is a developing country that is tasked with achieving its targeted development through thorough plans with minimum energy consumption and CO_2 emission. However, the predominant usage of fossil fuel combustion in this country due to extensive gasoline- and diesel-powered vehicles has underlined the consideration for energy use in this study.

The remainder of this article is organised as follows: the section on "Transport environmental Kuznets curve and the presence of corruption on environmental degradation" provides an in-depth review on the literature currently available and describes existing empirical findings of transport EKC. Then, the section on "Data description and preliminary analysis" delineates the use of data and shows the preliminary results, followed by the "Methodology" section detailing the analytical tools used in this study. Next, the section on "Estimation and discussion of results" presents and discusses the empirical results obtained. Finally, the "Concluding remarks and policy recommendations" section provides a summary of the findings and relevant policy implications.

Transport environmental Kuznets curve and the presence of corruption on environmental degradation

Throughout time, the EKC hypothesis has been widely discussed and debated among economists and environmentalists. Chowdhury and Moran (2012), for example, have stated that the economic growth of a country is associated with high CO_2 emissions, wherein such environmental degradation may be compensated by an even higher national income after the optimum point is reached. Therefore, testing the EKC hypothesis at the sectoral level renders it important to emphasise on the transport sector as this can ensure a favourable socioeconomic development, particularly in the developing countries. In fact, the driving force for transport demand can be ultimately pinpointed on economic growth, which results in climate change. Hence, the general reliance on transport appears to become a major source of emissions, thereby causing a long-term damage to the environment.

To explain the relationship between transport CO_2 emissions and economic growth, some studies have opted to validate the existence of the transport EKC hypothesis. For instance, Cole et al. (1997) have demonstrated that the EKC hypothesis holds true in the transport sector among a few European countries over their sample period of 1970–1992. Meanwhile, their bid to study the effect of economic growth on plumb emissions among 48 countries has allowed Hilton and Levinson (1998) to verify that their results are also in support of the EKC hypothesis within the same sector. Similarly, in studying the energy intensity of private and public transportation, Tanishita and Miyoshi (2007) have validated an inverted U-shaped EKC across the regions within the United States.

In the context of Latin American and Caribbean countries, 20 nations have been collectively sampled for the period from 1980 to 2005 by Timilsina and Shrestha (2009a) to demonstrate the driving force of transport CO_2 emissions towards economic growth and transport energy intensity. This rings true in most cases, whereby economic growth has been found to be responsible for the increasing trend of transport sector CO_2 emissions in Argentina, Brazil, Costa Rica, Peru, and Uruguay. In contrast, transport energy intensity drives CO_2 emissions in Bolivia, the Caribbean, Cuba, Ecuador, Guatemala, Honduras, Panama, and Paraguay. The scholars then have proceeded to extend their work (Timilsina and Shrestha 2009b) in the context of Asian countries, wherein they successfully obtain a similar finding.

Meanwhile, the use of the fully modified ordinary least squares cointegration approach has allowed Saboori et al. (2014) to examine the causal effect between economic growth and transport CO_2 emission in the road sector. As a result, the outcomes reveal an initially positive response of CO_2 emissions to economic growth during the period from 1960 to 2008 in most OECD countries. In contrast, Xu and Lin (2015) have adopted provincial panel data spanning from 2000 to 2012 to examine the effect of energy efficiency, private vehicles, and economic growth on CO_2 emissions in the context of transport sector in China. Their use of a nonparametric additive regression model has yielded findings in support of the existence of an inverted U-shaped EKC at the provincial level. In the context of Tunisia, Talbi (2017) has applied vector autoregressive modelling to confirm that economic development follows an inverted U-shaped pattern in relation to the total CO_2 emissions for road transport for the period of 1980–2014.

Nonetheless, some studies have refuted the existence of an inverted U-shaped relationship between economic growth and transport CO_2 emission, thus indicating that a higher economic development does not necessarily warrant greater collective efforts to reduce environmental pollution. For instance, Cox et al. (2012) conducted a postal questionnaire survey by focusing on six case study areas in Scotland in the year of 2006. The survey data obtained, however, did not yield results capable of validating the EKC hypothesis for household transport emissions, instead suggesting that richer households still do not choose to internalise the social cost of vehicle emissions. Meanwhile, a Tunisia-based study by Abdallah et al. (2013) has incorporated multivariate cointegration and causality analysis to examine the nexus between transport value added, road transport-related energy consumption, road infrastructure, fuel price, and CO_2 emissions for the period of 1980–2010. The subsequent outcomes obtained indicate that transport value added and transport CO_2 emissions both exhibit an N-shaped relation with two turning points of income.

Furthermore, a work specifically detailing on ASEAN-5 economies from 1971 to 2008 by Chandran and Tang (2013) has amalgamated the analysis of cointegration and Granger causality to examine the impacts of transport energy consumption, foreign direct investment, and income on CO_2 emissions. Their results then indicate the greater role played by economic growth in contributing towards CO_2 emissions in these economies, except the inverted U-shaped EKC hypothesis does not apply to Indonesia, Malaysia, and Thailand. In the context of Malaysia specifically for the period of 1975–2011, Azlina et al. (2014) have demonstrated a long-run relationship among income, transport energy consumption, CO_2 emission, structural change in the economy, and renewable energy use. Their multivariate model has thus revealed a U-shaped nexus between economic growth and environmental degradation in the domestic transport sector.

Besides, Liddle (2015) has opted to consider different types of transport pollutant such as carbon monoxide, nitrogen oxide, and volatile hydrocarbons in testing the EKC hypothesis. Data sourced from 84 cities in developed and developing countries both spanning from 1998 through 2000 have been subjected to testing, whereby it is found that per capita urban transport-related emissions increase and then decline at the observed income levels. In line with this, the autoregressive distributed lag approach has been implemented by Alshehry and Belloumi (2017) to examine the causal relationship between GDP per capita and transport CO_2 emission in the context of Saudi Arabia. These scholars report the long-run outcome of GDP per capita causing transport CO_2 emissions However, the results of a causality test does not support the EKC hypothesis.

Alternatively, a panel data set encompassing the European Union-27 countries and bracketed within the period of 1995 to 2009 has been utilised by Pablo-Romero et al. (2017) in order to estimate the transport Kuznets curve. However, their empirical results show that the turning point of improved environmental quality could not be achieved. Meanwhile, Wang et al. (2018b) have opted to consider China-based passenger and freight transportation sectors over the period from 1990 to 2015, thus finding that a high GDP per capita promotes the increase of CO_2 emissions in both sectors. Similarly, the presence of a significant regional disparity in China's multi-freight transport carbon emissions has resulted in Lv et al.'s (2019) exploration into the driving factors of carbon emissions. Limited to the freight transport sector and over the period of 1989 through 2017, the scholars noted an inverted U-shaped relationship between some freight emissions with GDP per capita.

Besides economic development, corruption is another possible determinant of environmental quality in the EKC framework, which has resulted in several studies carried out to examine its role in influencing environmental stress either directly or indirectly. For instance, Fredriksson and Svensson (2003), Fredriksson et al. (2003), Damania et al. (2003), and Varoudakis et al. (2007) have all revealed the tendency for the government that holds financial integrity and rigorous governance to be more effective in enforcing government rules and regulating CO_2 emissions. Subsequently, a better institutional quality of a country will foster a favourable environment towards the implementation of pro-environmental policies. Moreover, theoretical studies conducted by Lopez and Mitra (2000) and Fredriksson et al. (2004) have demonstrated that higher levels of corruption due to any flaw in the governance structure tend to reduce the stringency of environmental rules and regulations, thereby increasing the environmental stress.

It is worth noting that the impact of corruption on environmental quality is a veritable challenge for developed and developing countries alike, wherein several studies have revealed that a low level of corruption is associated with minimal CO_2 emissions. For instance, Pellegrini and Gerlagh (2006) have performed ordinary least squares estimation on a cross section of countries, thus demonstrating that only those with a history of democratic rule tend to be less corrupted and leading to better environmental quality. In line with this, an investigation into the manner in which corruption influences the income level at the turning point of the relationship between sulphur emissions and income has been carried out by Leitao (2010). The scholar examines a panel of 94 countries spanning over the period from 1981 to 2000 with a wide range of development and corruption levels. The results indicate that countries with a higher degree of corruption would have a higher per capita income at the turning point of EKC.

Contrastingly, studying 25 Sub-Saharan African countries throughout 1996–2010 has resulted in Abid (2016) not finding any evidence in support of the EKC hypothesis. In particular, the author's results confirm the possibility that the control of corruption can reduce CO_2 emissions directly through institutional quality, whereas it achieves this indirectly through economic growth and trade openness. Meanwhile, a look into Asia-Pacific Economic Cooperation countries by Zhang et al. (2016) and their application of the quantile regression approach have demonstrated an inverted U-shaped EKC in the presence of corruption. The real economic per capita at the EKC turning point may increase when CO_2 emissions increase, whereby the occurrence of corruption in low-emission countries would only worsen the environmental quality specifically. In contrast, high-emissions countries have been associated with a non-existent effect of corruption on the environmental quality.

Next, Wang et al. (2018a) have attempted an exploration by applying a partial least square regression model into the moderating role of corruption on the relationship between growth and CO_2 emissions. By observing BRICS countries for the sample period of 1996–2015, the resulting outcomes indicate that a control of corruption can moderate and weaken the relationship between economic growth and CO_2 emission by an indirect reduction of pollution level. Meanwhile, implementing the generalised method of moments has allowed Masron and Subramaniam (2018) to demonstrate the tendency for a higher level of pollution in developing countries having an extended degree of corruption throughout the sample period of 2005–2013. Alternatively, Sekrafi and Sghaier (2018) have examined the direct and indirect effects of control of corruption on economic growth and CO_2 emissions in Tunisia by using the autoregressive distributed lag cointegration framework. As a result, their outcomes for the post-revolution period of 1984–2012 typically characterised by a remarkable increase in corruption have indicated the positive effect of control of corruption on economic growth. Such effect can be further transposed indirectly via the negative effect of control of corruption on CO_2 emissions.

In line with this, the high level of corruption among African countries has spurred Habib et al.'s (2018) attempt to examine the manner in which corruption may influence CO_2 emissions. Using a sample of 18 selected countries located in Africa for the sample period from 1992 to 2013, the scholars have noted that more corruption may directly reduce CO_2 emissions in low-emission countries, whereas this is not applicable in high-emission countries. This outcome has been obtained by the use of the panel quantile regression approach and generalised method of moments accordingly. Similarly, Sinha et al. (2019) have conducted a study on BRICS countries throughout 1990–2017, yielding an inverted N-shaped EKC. This indicates that public sector corruption can cause environmental degradation. Meanwhile, another study by Ozturk et al. (2019) has explored the context further, wherein the researchers look into the impact of corruption control on energy efficiency in 60 countries for the period of 2000–2017. The results have shown that low corruption can provide more energy efficiency for all income groups in general. By considering China, India, Japan, Russia, and the United States which have high CO_2 emissions, Liu et al. (2020) perform the panel analysis to demonstrate that political, economic, and institutional governance could enhance environmental quality.

Corruption is a poverty-driven affliction, indeed. In line with this train of thought, a few studies have further substantiated its non-contribution to any direct effect on CO_2 emissions, whereas it only moderates the effect via economic growth. For instance, Cole (2007) has examined the direct and indirect impacts of corruption on air pollution emission by utilising data spanning 94 countries and covering the period from 1987 to 2000. As a result, the author has revealed the lack of such direct effect by corruption on carbon emissions; regardless, it is negatively correlated with environmental degradation. Additionally, Lægreid and Povitkina (2018) have positioned the weakly moderating role of corruption on the relationship between economic growth and CO_2 emission.

Overall, a large body of literature posits a link between economic growth and pollution. However, it is thus far noted that a limited number of studies have focused on CO_2 emissions in the transport sector for developing countries. Besides, no study has yet to attempt validating the transport EKC hypothesis in the presence of corruption. To fill such a gap, this study aims to contribute new knowledge to the existing literature in several different ways. First, even though empirical assessments detailing the impact of corruption on the environment are rare in terms of overall CO_2 emissions, the emphasis is placed on the EKC hypothesis validity in the context of the Malaysian transport sector, wherein transport CO_2 emission is chosen as the dependent variable. Second, an analysis involving the use of panel data is found to be preferable among researchers in order to test the EKC hypothesis and examine the environmental consequences of corruption. Currently, available cross-country studies have only provided a general understanding of the relationship among the variables, which will be remedied in this work by concentrating on one developing country only, namely, Malaysia. Accordingly, single-country studies are positioned as vital towards providing policy directions to each of the individual countries.

Data description and preliminary analysis

For the purpose of this study, data employed included transport CO_2 emission (CO_2), gross domestic product per capita

(*GDP*), corruption (*Cor*), and energy use (*EU*) for Malaysia spanning a period from 1990 to 2017, yielding a total of 28 observations. These data were sourced from the Global Energy Statistical Yearbook, World Development Indicators (WDI) database, and International Country Risk Guide (ICRG).

In terms of Malaysia, CO_2 is produced as a result of fuel combustion in all transport activities, which include domestic aviation, domestic navigation, road, rail, and pipeline transport and exclude international marine bunkers and international aviation. This element is expressed in million tonnes of CO_2 equivalent, wherein its impact on CO_2 is in line with the principle of parsimony and in consideration of three variables as the explanatory variables. These variables include (i) *GDP* as the real gross domestic product divided by midyear population and measured in constant 2005 prices (i.e. Malaysian ringgit); (ii) *Cor* as financial corruption in the form of demands for special payments and bribes connected with import and export licences, exchange controls, tax assessments, police protection, or loans; and (iii) *EU* as the final consumption of motor petrol, where it is measured in kilotonne of oil equivalent.

In general, the corruption index published by the ICRG is employed to evaluate the degree of corruption, whereby it originally ranges from 1 to 6. Here, a score of 6 points equates to "very low risk", while conversely a score of 1 point indicates "very high risk". Table 1 shows the descriptive statistics for the variables used in this study. First, the average annual transport CO_2 emission was 39.6125 million tonnes during the sample period, whereas the maximum transport CO_2 emission recorded was 79.5273 million tonnes. The real GDP per capita showed the mean value of RM25216.370 as shown in the table. Moreover, the corruption index yielded a maximum value of 4 and indicated a low risk of corruption, while its minimum value of 2 was suggestive of a high risk for corruption. Lastly, the final consumption of motor petrol generated a mean value of 7717.2857 kilotonnes.

Methodology

Facilitating a practical analysis of the EKC hypothesis required an examination of the relationship between CO_2 emissions and income through a nonlinear quadratic form. The model specification is proposed as follows:

$$LCO_{2t} = \beta_0 + \beta_1 LGDP_t + \beta_2 LGDP_t^2 + \beta_3 LCor_t + \beta_4 LEU_t + \varepsilon_t \; \varepsilon_t \sim N(0,1) \quad (1)$$

where LCO_{2t} denotes the natural logarithmic value of CO_2 emissions from transport at time t, $LGDP_t$ is the natural logarithmic value of real GDP per capita at time t, $LGDP_t^2$ represents the squared value of natural logarithmic real GDP per capita at time t, $LCor_t$ refers to the natural logarithmic value of corruption at time t, LEU_t denotes the natural logarithmic value of oil consumption at time t, and ε_t is the white noise disturbance at time t.

Based on Eq. 1, the EKC hypothesis held itself well when the coefficient of GDP_t had a positive sign ($\beta_1 > 0$) and the coefficient of GDP_t^2 displayed a negative sign ($\beta_2 < 0$). According to the inverted U-shaped hypothesis, environmental deprivation would be reached at the maximum level of GDP (GDP_m), which should be equal to $\beta_1/2\beta_2$. Then, the maximum level of CO_2 emissions (CO_{2m}) was obtained by substituting the value of GDP_m into the right-hand side of Eq. 1. When the GDP is achieved beyond this maximum level, the CO_2 emissions would be subsequently reduced and thus indicated that their impact on the economy was weak, thereby improving the environmental quality. Moreover, the remaining explanatory variables such as corruption and oil consumption within the model would be regarded in addition to real income per capita because they are external to the carbon dioxide–income system. Additionally, in line with the works of Cole (2007, p. 639), Abid (2016, p.88), Masron and Subramaniam (2018, p.12496), Sekrafi and Sghaier (2018, p.84), and Sinha et al. (2019, p.1383), it would be entirely plausible to formulate a linear relationship between CO_2 emission and corruption by assuming the direct impact of corruption on environmental degradation.

Table 1 Summary descriptive statistics of the variables (1990–2017)

	Source	Unit measurement	Mean	Std. dev.	Max	Min
CO_2	Global Energy Statistical Yearbook	Million tonnes	39.6125	18.1087	79.5273	14.7389
GDP	WDI	Malaysian ringgit	25216.370	6208.0291	37111.757	14607.14
Cor	ICRG	6 points	2.9643	0.6929	4	2
EU	Global Energy Statistical Yearbook	Kilotonne of oil equivalent	7717.2857	3214.5591	13500	2901

CO_2 denotes the carbon dioxide emissions in the transport sector, *GDP* denotes the real gross domestic product per capita, *Cor* denotes the corruption index, and *EU* denotes the energy use

Next, an analysis of the driving forces for transport CO_2 emissions was generated by performing the following three steps. First, the stationarity of the time series processes was examined in determining the regression model selection; if the time series follows a non-stationary process, the conventional OLS estimation method will lead to a spurious regression problem. Therefore, it is undeniably crucial to assess the stationarity of each variable via the unit root test, which is carried out by using Eq. 2 as follows:

$$\Delta y_t = \alpha y_{t-1} + \varpi_t^{'}\delta + \varepsilon_t \quad (2)$$

To test the unit root for each series, the Phillips-Perron (PP) unit root test (Phillips and Perron 1988) was chosen as the nonparametric method employed to correct any serial correlation and heteroscedasticity in the error terms (Lanne et al. 2002). As a result, both elements would not affect the asymptotic distribution of the test statistic. The PP test statistics can be obtained as follows:

$$\tau_\alpha = t_\alpha \left(\frac{\gamma_0}{f_0}\right)^{1/2} - \frac{T(f_0 - \gamma_0)(se(\alpha^\Lambda))}{2f_0^{1/2}s} \quad (3)$$

The asymptotic distribution of the PP-modified ratio was similar to that of the augmented Dickey-Fuller statistics. Here, the test statistics value, which was lower than the MacKinnon lower-tail critical value, successfully generated rejection of the null hypothesis of a series following the unit root process ($\alpha = 0$), implying a stationary time series.

Second, the use of two cointegration tests would allow one to detect the existence of a long-run relationship among these non-stationary series. These tests included both the Hansen's instability and Park's added variables tests. In brief, Hansen's instability test is developed by Hansen (1992) in order to serve as a cointegration test for the null hypothesis, wherein the underlying series are thus cointegrated with the first order against the alternative hypothesis of no cointegration. Therefore, obtaining the evidence of parameter instability in the hypothesis testing rendered it crucial for an evaluation of the parameter stability. This could be done by using the following test statistics, which is generated from the Lagrange Multiplier test for parameters:

$$L_C = \sum_{t=2}^{T} \overset{\Lambda}{S}_t{}' G^{-1} \overset{\Lambda}{S}_t \quad (4)$$

where $S^\Lambda{}_t = \left(Z_t u^{\Lambda^+}{}_t\right) - \begin{bmatrix} \overset{\Lambda^+}{\lambda}_{12'} \\ 0 \end{bmatrix}$, $S^\Lambda{}_t$ is defined for the subset of original regressors of Z_t, $G = \omega^\Lambda{}_{1.2}\left(\sum_{t=2}^{T} Z_t Z_t^{'}\right)$ and G is computed by using the method employed in calculating the original coefficient standard errors.

Besides, Park's added variables test can be performed by estimating the following spurious regression model. This model consists of the spurious powers for the trend from $p + 1$ to q:

$$y_t = X_t^{'}\beta + \sum_{s=0}^{p} t^s\gamma_s + \sum_{s=p+1}^{q} t^s\gamma_s + u_{1t} \quad (5)$$

Based on Eq. 5 above, the joint significance of the coefficients' tests for $\gamma_{p+1}, \ldots$ and γ_q is thus tested accordingly. Under the null hypothesis of cointegration, these coefficients should be insignificant due to the stationary residual. Meanwhile, the alternative hypothesis yielded spurious trend terms that would mimic the remaining stochastic trend in the residual. Here, the joint Wald test was then applied to test the null hypothesis by using the test statistics following an asymptotically chi-squared distribution with the $(q-p)$ degree of freedom.

Third, a long-run model was established accordingly given the presence of cointegration relationship between transport CO_2 emissions, real GDP per capita, real GDP per capita square, corruption index, and oil consumption in Malaysia. In particular, the long-run estimation of the transport CO_2 emissions model was performed to test the EKC hypothesis and investigate the effects of corruption and oil consumption on CO_2 emissions in the transport sector. To this end, three cointegrating techniques were utilised to control for endogeneity and serial correlation in the regressor matrix, namely, fully modified ordinary least squares (FMOLS) by Phillips and Hansen (1990), canonical cointegrating regression (CCR) by Park (1992), and dynamic ordinary least squares (DOLS) by Stock and Watson (1993). These techniques could be differentiated based on different correction mechanisms for the second-order bias and non-centrality bias in providing asymptotically identical estimates. More importantly, they could be applied to stationary and non-stationary variables alike.

The FMOLS is a nonparametric technique that can also be used to transform residuals from the cointegration regression, as well as to get rid of nuisance parameters. It involves the transformation of data and estimates that can eradicate any issues of endogeneity and serial correlation effect in the regressors. Accordingly, it is appropriate to be applied under two conditions, which are as follows: (1) it allows for one integrating vector, and (2) the explanatory variables are not cointegrated among themselves. Assuming these conditions are met, the FMOLS model specification is in the following form:

$$LCO_{2t} = \sigma_0 + \sigma_1^{'}X_t + \mu_t \; t = 1, 2, \ldots, n \quad (6)$$

where CO_{2t} is an $I(1)$ and X_t is a $(k \times 1)$ vector of $I(1)$ regressors, which are not cointegrated among themselves. Therefore, it is assumed that X_t has the following first difference stationary process:

$$\Delta X_t = \eta + v_t \; t = 1, 2, \ldots, n \tag{7}$$

where η is a $(k \times 1)$vector of drift parameters and v_t is a $(k \times 1)$ vector of stationary variables. It is assumed that $\varpi = \left(\mu_t, v_t^{'}\right)^{'}$ is strictly stationary with zero mean and a finite positive-definite covariance matrix Σ.

In general, FMOLS provides optimal estimates of the cointegrating regressions and does not sacrifice a large degree of freedom. As a result, it can produce an asymptotically unbiased and fully efficient mixture normal asymptotic estimator, which is given as:

$$\varphi_{FMOLS} = \left(\sum_{t=1}^{T} Z_t Z_t^{'}\right)^{-1} \left(\sum_{t=1}^{T} Z_t y_t^{+} - T\hat{\mathcal{J}}^{+}\right) \tag{8}$$

where $y_t^{+} = y_t - \hat{\lambda}_{ox}\hat{\lambda}_{xx}^{-1}$, Δx_t is the correction term for endogeneity, $\hat{\lambda}_{ox}$ and $\hat{\lambda}_{xx}$ are the kernel estimates of the long-run covariance, $\hat{\mathcal{J}} = \hat{\Delta}_{ox} - \lambda^{\cdot\cdot}{}_{ox}\hat{\lambda}_{xx}^{-1}\hat{\Delta}_{xx}$ is the correction term for serial correction, and $\hat{\Delta}_{ox}$ and $\hat{\Delta}_{xx}$ are the kernel estimates of the one-sided long-run covariance.

Next, the DOLS is a parametric technique typically used to deal with two estimation problems. First, the model can tackle the problem of simultaneity by modelling the leads and lags of the regressors, wherein a cointegrating regression model consisting of the lead and lagged differences will eliminate the problems of asymptotic endogeneity and serial correlation. Second, it allows for the study variables to be integrated into alternative or higher orders (Stock and Watson 1993). This technique is based on the following system with a certain number of cointegrating vectors:

$$\begin{gathered} \Delta X_t^1 = k_t^1 \\ X_t^2 = \varphi_0 + \varphi X_t^1 + k_t^1 \end{gathered} \tag{9}$$

where $X_t^{'} = \left[X_t^{1'} \middle| X_t^{2'}\right]$. The dimensions of X_t^1 and X_t^2 being $(p-r) \times 1$ and $(r-1)$, respectively.

Based on Eq. 9, the leads and lags of $\Delta X_t^{'}$ were thus incorporated to render the error process stationary. To this end, the Stock-Watson DOLS model is specified as follows:

$$\begin{aligned} LCO_{2t} = {} & \alpha + \beta_1^{'} LGDP_t + \beta_2^{'} LGDP_t^2 + \beta_3^{'} LGor_t \\ & + \beta_4^{'} LEU_t + \sum_{i=-K}^{K} \theta_{1i} \Delta LGDP_{t-i} \\ & + \sum_{i=-K}^{K} \theta_{2i} \Delta LGDP_{t-i}^2 + \sum_{i=-K}^{K} \theta_{3i} \Delta LCor_{t-i} \\ & + \sum_{i=-K}^{K} \theta_{4i} \Delta LEU_t + \mu_t \end{aligned} \tag{10}$$

By using the OLS method, the normalised cointegrating vectors (φ) were thus estimated in order to obtain an estimator asymptotically equivalent to the maximum likelihood estimators. This would leave sufficient observations for the initial and terminal conditions for the leads and lags of the data in X_t. The estimator in the DOLS regression is as shown below:

$$\hat{\varphi}_{DOLS} = \left[\left(\sum_t X_t X_t^{'}\right) \otimes I_{k_t}\right]^{-1} \left[\sum_t \left(X_t \otimes I_{k_t}\right) \left(\Delta^{d-1+1} Y_t^{l}\right)\right] \tag{11}$$

Meanwhile, the CCR is an estimation technique generally implemented to transform the set of variables included in the cointegrating regression. The transformations are given by:

$$y_t^* = y_t - \left(\sum^{-1} \Gamma_2 \alpha + \left(0, \omega_{12} \Omega_{22}^{-1}\right)^{'}\right)^{'} w_t \tag{12}$$

$$x_t^* = x_t - \left(\sum^{-1} \Gamma_2\right)^{'} w_t \tag{13}$$

$$e_t^* = \sigma_t \left(u_t - \omega_{12} \Omega_{22}^{-1} \Delta X_t\right) \tag{14}$$

where e_t^* is asymptotically independent of the innovations for the regressor$\left(\Delta X_t^{'}\right)$.

To this end, these transformations were generated to asymptotically eliminate second-order bias and endogeneity caused by the long-run correlation. This could be done by estimating the nuisance parameters for the long-run covariance of the disturbances in the system. The CCR model is specified as follows:

$$y_t^* = \alpha^{'} x_t^{*'} + e_t^* \tag{15}$$

This technique involved two stages, whereby the first stage implemented the ordinary least squares method to estimate the cointegrating regression model. Following this, the second stage utilised the obtained estimates for the cointegrating vector to form an estimation for the nuisance parameters. As a result, the CCR estimator is as shown below:

$$\hat{\varphi}_{CCR} = \left(\sum_{t=1}^{T} Z_t^* Z_t^{*1}\right)^{-1} \sum_{t=1}^{T} Z_t^* Y_t^* \tag{16}$$

where $Y_t^* = \left(X_t^{*1}, D_t^1\right)$, $X_t^* = X_t - \left(\hat{\Sigma}^{-1} \hat{\kappa}_2\right) \hat{v}_t$, and $Y_t^* = Y_t^* - \hat{\Sigma}^{-1} \hat{\kappa}_2 \hat{\beta} + \left[\hat{\eta}_{22}^{-1} \hat{\omega}_{21}\right]^{'} \hat{v}_t$. $\hat{\beta}$ is an estimate of the cointegrating equation coefficients, $\hat{\kappa}_2$ is the second column of $\hat{\kappa}$, and $\hat{\Sigma}$ denotes estimated contemporaneous covariance matrix of the residual.

Estimation and discussion of results

To reduce variation and induce stationarity concurrently in the variance-covariance matrix, all variables at time were converted into their natural logarithmic form, whereby their respective stationarity must be examined before performing the estimations. If the condition of stationarity is not met, spurious results can be obtained. Hence, performing the PP unit root test allowed this to be prevented and detected whether each variable in the level form followed a unit root process. Then, this testing is followed by cointegration testing and long-run model estimation.

The results of the PP unit root test are presented in Table 2 for each variable accordingly. It was performed by using two auxiliary models, namely, a drift-only model and another model consisting of draft and deterministic trend. Following this, its outcomes would clearly indicate a non-rejection of the null hypothesis for all variables at the level form and rejection of the null hypothesis for variables at the first difference based on test statistics. Therefore, it substantiated the conclusion that all variables followed the process of integration at order one, thereby confirming that they contained a unit root and followed the difference stationary process. Due to the results demonstrating that the non-stationary process was adhered by all variables in levels, the next process of cointegration analysis was carried.

Using the results of common integration properties for the study variables as shown in Table 2, testing for the transport CO_2 emissions, real GDP per capita, real GDP per capita square, corruption, and oil consumption for cointegration purposes was done to determine whether a long-run relationship was present in the econometric specification. Therefore, the presence of cointegration among non-stationary variables is tested by using Hansen's and Park's procedures for the purpose of hypothesis testing accordingly and the outcomes are summarised in Table 3.

Table 3 displayed test statistics of 0.3054, 2.5057, and 2.9353, thereby establishing the non-rejection status for the null hypothesis of cointegration. Henceforth, both tests demonstrated strong evidence in favour of cointegration among the variables tested, thereby substantiating the long-run relationship present between them. As a result, the long-run relationship of real GDP per capita, squared value of GDP per capita, corruption, and oil consumption with respect to transport CO_2 emissions was derived accordingly. This allowed the estimation of the long-run parameters for all variables in the level form along with their approximate asymptotic standard errors. For the purpose of robustness check, the long-run estimates were performed using three techniques, namely, FMOLS, DOLS, and CCR. The results are summarised in Table 4.

The robustness of the results was checked following the estimation using the FMOLS, DOLS, and CCR, thereby establishing two similar findings. First, all independent variables yielded a significant effect on transport CO_2 emissions, whereby it should be noted that the impact of oil consumption on the emissions was positive at 1% level. Following this, the estimation results of FMOLS and CCR both were similar: corruption would significantly influence the transport CO_2 emissions at the level of 5%. However, the results of estimation using the DOLS indicated that such impact was only significant at the level of 10%. Second, the coefficient sign for each significant variable remained unchanged, thereby suggesting that the results were robust and appropriate with a small sample size.

Based on these empirical results, two empirical problems highlighted in the literature were successfully resolved. First, one of the major gaps in literature was the scarcity of empirical study itself towards providing new insights regarding the role of corruption in influencing environmental stress in the transport sector. Accordingly, this study resolved this by reinvestigating the manner in which it could influence transport CO_2 emissions in the context of Malaysia and covering the period spanning from 1990 to 2017. Second, the issue of EKC hypothesis validation from the perspective of transport CO_2 emissions was solved. However, such characterisation of the EKC has yet to be explored rigorously in the context of Malaysia.

Examining the effect of corruption on transport CO_2 emissions

Empirically, no clear-cut answer could be given in order to properly enunciate the extent to which transport CO_2 emission

Table 2 Results of the Phillips-Perron (PP) unit root tests

	Level		First difference		I(d)
	Drift	Drift and trend	Drift	Drift and trend	
LCO_2	− 0.8238 (3)	− 2.0592 (0)	− 5.7559*** (1)	− 5.6708*** (1)	1
LGDP	− 1.5215 (3)	− 3.0953 (3)	− 4.7730*** (4)	− 4.7420*** (4)	1
$LGDP^2$	− 1.3414 (3)	− 3.0160 (3)	− 4.8393*** (4)	− 4.7786*** (4)	1
LCor	− 1.4268 (4)	− 1.4406 (4)	− 6.6414*** (2)	− 6.7413*** (3)	1
LEU	− 1.9027 (6)	− 2.4519 (2)	− 6.5560*** (2)	− 6.9007*** (3)	1

The critical values are based on McKinnon. Bandwidth is reported in ( ), where its value is determined from the Newey-West automatic by using the Bartlett kernel. *** indicates that the null hypothesis of a series has a unit root that is rejected at the significance level of 1%. I(d) stands for order of integration

Table 3 Results of cointegration tests

Hansen parameter instability				
Lc statistic	Stochastic trends (*m*)	Deterministic trends (*k*)	Excluded trends (*p*2)	*p*-value
0.3054	4	0	0	0.2
Park added variables				
Added trends		Chi-square statistic	df	*p*-value
Linear trend		2.5057	1	0.1134
Quadratic trend		2.9353	2	0.2305

This *Lc* statistic is based on Phillips and Hansen (1990) parameter estimates. $L_C(m2 = 4, k = 0)$, where $m2 = m - p2$ is the number of stochastic trends in the asymptotic distribution. The null hypothesis states that LCO_2, $LGDP$, $LGDP^2$, $LCor$, and LEU are cointegrated.

was sensitive to corruption. As observed in Table 4, the coefficients associated with corruption index are significant at the level of 5% by applying FMOLS and CCR, while it is only significant at the level of 10% when DOLS is implemented. Furthermore, these coefficient values depicted a priori expected negative sign, indicative of the contributory role of a low-risk corruption towards the reduction of transport CO_2 emissions. In general, any corruption index (low risk of corruption) increment by 1% is capable of reducing the quantity of CO_2 emissions in the transport sector by around 0.23–0.26%. Therefore, the results showed that a marginal reduction of transport CO_2 emissions emitted into the atmosphere would be less sensitive to a marginal increase in corruption. This could be explained by the manner in which increased corruption led to the weakened environmental regulations, otherwise achieved by introducing a bias in the process of regulation adoption and implementation. In other words, a higher level of corruption could lower the stringency of environmental regulations, thereby making the political structure unable to respond through the implementation of appropriate environmental legislation. This might inevitably result in increased transport CO_2 emissions.

As evidenced in this study, the presence of corruption spurred a higher rate of transport CO_2 emissions. Transport-related infrastructure provision in Malaysia typically involves a large number of public funds utilised across different complex projects, which are carried out via bilateral trade and diplomatic relations between the country and others. For example, the negotiations between Malaysia and Singapore, as well as China, respectively, have been formed in order to implement several local transport-related projects, which include Pan Borneo Highway, East Coast Rail Link, Light Rail Transit Line 3, and Kuala Lumpur–Singapore high-speed rail, among others. Such mega transport-related projects are prone to corrupted practices, which may divert the originally obtained funding. Accordingly, the resources dedicated to these projects diverted from the required maintenance funding could contribute to the environmentally harmful practices.

Table 4 Long-run parameter estimates of transport CO2 emissions

	FMOLS		CCR		DOLS	
	Coefficient	*t* statistic	Coefficient	*t* statistic	Coefficient	*t* statistic
Constant	45.3118** (19.9093)	2.2759	43.9880** (16.6184)	2.6469	40.6993 (25.9052)	1.5711
$LGDP_t$	− 9.9254** (3.9119)	− 2.5372	− 9.6869*** (3.2950)	− 2.9398	− 9.0393* (4.9818)	− 1.8145
$LGDP_t^2$	0.5095** (0.1920)	2.6544	0.4950*** (0.1625)	3.0471	0.4469* (0.2431)	1.8381
$LCor_t$	− 0.2561** (0.0965)	− 2.6537	− 0.2417** (0.1000)	− 2.4175	− 0.2386* (0.1186)	− 2.0113
LEU_t	0.7639*** (0.1338)	5.7077	0.8068*** (0.1579)	5.1087	0.9940*** (0.2022)	4.9154
Adj.R^2	0.9813		0.9809		0.9907	
SER	0.0622		0.0629		0.0421	
SSR	0.0851		0.0871		0.0230	
LRV	0.0027		0.0027		0.0020	

SER stands for standard error of regression. SSR stands for sum squared residual. LRV stands for long-run variance estimate (pre-whitening with lags based on AIC maximum lag = 4, Bartlett Kernel, Newey-West fixed bandwidth). The standard error of estimates are due to Newey and West (1987) and robust in small sample. These robust standard errors facilitate a valid inference to be made upon the coefficients of the variables entering as regressors in levels. Standard errors of estimates are reported in ( ). The optimal leads and lags for DOLS are based on AIC. We estimate the long-run model through DOLS by including up to $i = \mp 1$ lead and lag and up to one lag of the equilibrium error without altering results to any significant degree. ***, **, and * denote statistical significance level at 1, 5, and 10%, respectively

As reported in Table 4, energy use as the final consumption of motor petrol positively influences CO_2 emissions in the transport sector. The results showed that the coefficient values of 0.7639, 0.8068, and 0.9940 were significant at the level of 1%. Such elasticities were positive and lower than 1, denoting that a rise in petrol consumption of motor vehicles would also increase the level of CO_2 emissions in the transport sector in a lesser amount rather than proportionally. Accordingly, this finding is in line with the work of He et al. (2005), Wang et al. (2007), and Cai et al. (2012) for China, Pongthanaisawan and Sorapipatana (2013) for Thailand, Lu et al. (2009) and Zhang et al. (2011) for Taiwan, and Paladugula et al. (2018) for India.

Validating the EKC hypothesis in the presence of corruption and energy use on transport CO_2 emissions

Prior to this, the EKC hypothesis argued that pollution would follow an inverted U-shaped pattern relative to the country's income level. Therefore, testing whether it was supportive in the context of the Malaysian transport sector entailed the inclusion of real GDP per capita and its quadratic term into the regression model. If the EKC hypothesis holds, then the coefficient values for this variable and its quadratic term are expected to be significant with positive and negative signs, respectively.

In the context of the long-run estimate robustness through the application of FMOLS, DOLS, and CCR, Table 4 shows the results of Eq. 1 estimation accordingly. Therefore, the coefficient associated with real GDP per capita was negatively significant, whereas that correlated with its squared term was positive and significant. Following this, the initial increment of income level will lead to a tendency for the transport CO_2 emissions to decline, which will then rise as the economy grows further. In other words, the EKC hypothesis was deemed not valid in the Malaysian transport sector. This finding is consistent with those of Chandran and Tang (2013) and Azlina et al. (2014), who have argued previously that this particular sector seems to be necessarily a U-shaped curve. Our results are also in line with the findings of Altıntaş and Kassouri (2020) who opine that an inverted U-shaped linkage does not exist between pollution and economic growth. Given the fact that Malaysia is still in its growing phase, a rejection of the conventional EKC hypothesis for the transport sector is unsurprising due to the possibility of the country having yet to achieve the desired level of income capable of enabling a reduced amount of transport CO_2 emissions.

Therefore, the U-shaped relationship between economic growth and environmental degradation in the Malaysian transport sector could be attributed and explained by one specific reason. In the early stage of its economic development, the country had a poor transportation system and low vehicle ownership, which would not contribute much to the CO_2 emission level. At this time, the mobility demand or car ownership was limited to those with higher income levels, resulting in a fall of the emission rates. When the people started to earn more following the growing economy, their affordability to own a vehicle increased accordingly, thus leading to a higher energy demand. In turn, this would deteriorate the environmental quality.

By looking at further examples, it should be noted that Malaysia has not been able to reduce its transport CO_2 emissions still in the long-term despite the various efforts expended for improving the environmental quality. This may be attributable to the lack of technology innovation adoption in the domestic transport sector. For example, construction of the North-South Expressway is geared towards spurring trade and commerce activities in the country but its presence remains incapable of resolving the basic problem of congestion. It attracts a huge volume of traffic, thereby contributing to a negative impact on the surrounding ecosystem and environmental quality.

Concluding remarks and policy recommendations

This study aimed to examine the impact of corruption on CO_2 emissions and validate the EKC hypothesis in the context of the Malaysian transport sector by using a data set spanning the period from 1990 to 2017. Accordingly, it successfully contributed to the literature by specifically emphasising on the impact of corruption on transport CO_2 emissions and the presence of EKC in the transport sector. This was achieved by adopting FMOLS, DOLS, and CCR techniques in performing the estimations and analysing the long-run relationship between the variables in order to ensure the robustness of the results obtained. The results provided the following notable findings accordingly. First, transport CO_2 emissions tend to increase parallel to the level of corruption, implying that a highly corrupt transport sector plays a role in causing environmental degradation. Second, the transport EKC hypothesis is not supported in Malaysia, suggesting that the country has yet to reach the level of economic growth required in reducing the transport CO_2 emissions.

As a result, it is important to deal with the growing environmental problems occurring due to the development of transport-related infrastructures. It is suggested for the policies to emphasise on specific components. First, it is strongly crucial for the government of Malaysia to develop policy instruments within the transport sector for an effective reduction of CO_2 emissions and improved governance mechanisms. In relation to this, the policymakers should make use of various anti-corruption initiatives to control bribery with the aid of law enforcing entities, such as the Road Transport Department, environmental protection agencies, and police forces. Second, the government is required to provide economic incentives for investors or businesses showing their keenness to engage in research and development in the area of transportation. Following this, improved technologies could contribute to a more efficient transportation system that will, in turn, reduce the level of such emissions. Third, the government will find it necessary to develop a sustainable transport policy aimed at controlling the rate of traffic growth, enhancing the environmental performance of vehicles, and creating public awareness about the environmental impact of transport pollutants.

This study did not incorporate interaction term and a high degree of the polynomial for the explanatory variables in the model specification in order to ensure the principle of parsimonious in avoiding the loss of freedom is met. Regardless, it brings forward a potential avenue for future research, wherein future works may want to look into the impact of corruption on transport CO_2 emissions by considering both the quadratic and cubic functions towards accommodating the possibility of an N-shaped relation.

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