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Energy, Trade, Urbanization and Environmental Degradation Nexus in Sri Lanka: Bounds Testing Approach

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Abstract: This study examines the nexus between energy, trade, urbanization and environmental degradation in Sri Lanka. The time series data has been checked for unit root problem along with unknown structural break. The bounds testing approach confirms the long-term relationship among carbon emissions, energy consumption, income, trade openness, and urbanization in the presence of structural break. The results of the study do not confirm the presence of the EKC (Environmental Kuznets Curve) hypothesis in Sri Lanka. This study finds that energy consumption leads to carbon emissions in both the long term and the short term. Trade openness is degrading environmental quality, as trade is responsible for the accumulation of carbon emissions in the atmosphere. The results of the study confirm that urbanization has been found to have significant and negative effect on carbon emissions. The study finds that the model is in equilibrium and the model will return to equilibrium from any external shock in less than two years. Policy measures are recommended for sustainable environment of the island.

Keywords: energy; environmental degradation; trade; urbanization

1. Introduction

Climate change is one of the core issues in the modern world and has economic, cultural, and ecological impacts on the society. Since the industrial revolution, fossil fuels consumption has increased the carbon emission which is one of the main roots of global warming and climate change in the world. Carbon emissions are being used as a proxy for environmental degradation in empirical studies [1–3]. The reason for this is that carbon emissions have a historical link with economic growth. However, the question arises why countries had different levels of carbon emissions per capita for the similar level of income per capita? To find a correct answer to this critical question, many studies have been attempted to study the nexus between environmental degradation and economic growth along with other important variables which fit in the context [3–8]. The Environmental Kuznets Curve

(EKC) hypothesis is currently a standard feature in the scientific literature of environmental policy [9]. This hypothesis shows an inverted U-shape nexus between environmental degradation and income level [10].

The urbanization process may be identified as a critical determinant of economic growth and structure of the economy. However, extensive urbanization is a recent phenomenon, and is among those that have been identified as an advanced process of modern economic development [11]. Although there is a high relationship between urbanization and economic growth, it is a difficult task to decide whether economic growth causes urbanization or urbanization causes economic growth [12]. On the other hand, the urbanization process may increase the commercial energy consumption and carbon emissions [13,14]. Several studies have included urbanization as factors of environmental degradation in both developing and developed economies [13,15].

Urbanization has positive as well as negative effects on the environment. The impact of urbanization on the environment differs with the level of development [16]. Several studies have observed a positive relationship between urbanization and carbon emissions [17,18]. Katircioglua and Katircioglub [19] pointed out that traditional fuel energy consumption related to urban development is a key path of carbon dioxide emissions. Also, Wu et al. [20] documented that the urbanization process and energy intensifies the level of carbon emissions in the environment. Aggregate energy consumption and greenhouse emissions are positively correlated with the urbanization process as the result of higher living standards in urban life. Urban citizens frequently attempt to consume high energy intensive goods. Thus, modern urban lifestyles lead to increase direct and indirect energy consumption and as a consequence lead to the global warming and climate change [21]. Also, urbanization is always the core of the socio-economic development of an economy. All hubs of economic development process such as finance, communication, and transportations are located in the cities. Conversely, urban life is always dynamic, and energy consumption is significantly higher in urban areas than rural areas. Thus, energy consumption in an urban area has a direct effect on environmental quality and urbanization is considered to be one of the leading elements in the estimation of future carbon emissions in the world. International Energy Agency [22] reported that urban areas are globally responsible for 71% of worldwide carbon emissions while some scholars recently documented that urbanization is responsible for 70 percent of total greenhouses gas emission [23]. Thus, urban energy consumption may cause to change the regional climatic conditions. However, it is not necessary that urbanization is always and everywhere responsible for environmental degradation. Azam and Khan [24] used carbon emissions as proxy for environmental degradation concluded that the effect of urbanization on environmental degradation can be positive or negative. There is some evidence for negative relationship between urbanization and carbon emissions [25,26]. Tupy [27] identified urbanization as a noble factor for improvement of environmental quality as result of high efficiency in resources consumption. Similarly, Effiong [28] has observed that urbanization can help in enhancing environmental quality. On the other hand, some researchers noted that urban lifestyles are significantly affecting energy intensity [23,29,30] and Tupy [27] opined that urbanization improves the public facilities. Thus, urbanization may lessen environmental degradation.

Grossman and Krueger [10] argued that trade liberalization may lead to lesser environmental damages because of two very important reasons. First, trade liberalization may leads to higher income levels and because of increase in the national wealth people may ask cleaner environment. Second, trade liberalization policies may encourage foreign direct investment and as a result modern technologies transfer to local economy. Thus, the production technique will put lesser pressure on environment as modern technologies are cleaner than older technologies. Nasir and Rehman [1] argued that trade structure matters for the environmental quality of a country and found that trade had detrimental effects on the environment. Haq et al. [2] also endorse this argument that trade structure matters for the environment however; trade may improve the environmental quality if the traded commodities are environmental friendly. The effects of trade on environment can be explained on bases of scale, technique, and composite effects [2,10]. Scale effect is based on the argument that trade liberalization results in extensive depletion of resources for more production thus; enhances carbon emissions. Whereas, technique effect of trade refers to diffusion of technology among countries and production is made environment friendly through efficient technologies. Moreover, trade enhances domestic competition so that domestic producers focus on efficient production techniques. Lastly, the composition effect refers to the composition of exports and imports. If a country trade surpasses in cleaner industries then trade will decrease emissions level and dirty industries dominate in trade then, trade will deteriorate the environment. Thus, whether trade improves or deteriorates environment is not settled in the literature [1,2].

Sri Lanka is a lower-middle income developing island of 21 million people, located in the south-eastern part of the southern tip of the Indian subcontinent. As a country, Sri Lanka was the first South Asian nation to liberalize its trade and investment regime in 1978. Trade openness which is the ratio of foreign trade to GDP is depicted in Figure 1 for the selected South Asian countries. Since 1978 to 2008, if one compares the Sri Lankan economy with other major economies of South Asia the ratio of trade to GDP is very high for Sri Lanka. However, the trade openness of Sri Lanka is fluctuation around 50% since 2009.

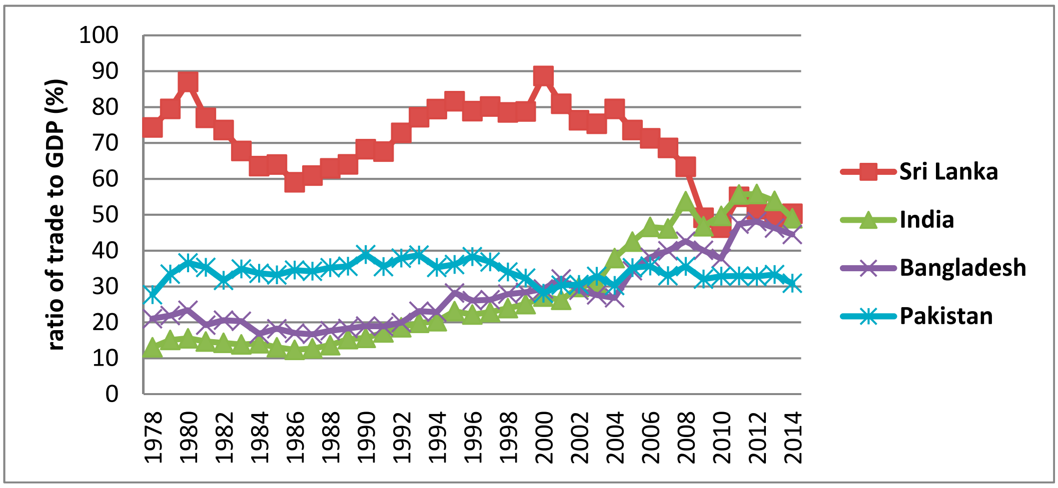

Figure 1. Trade openness in selected South Asian countries.

In 2016, the total worth of the Sri Lankan economy was US$ 83 billion with per capita income US$ 3835 [31]. The main sectors of the economy are inbound tourism, tea export, textile and apparel products, rice and other agricultural products. However, it is becoming knowledge-based economy as Sri Lanka has produced the second largest number of chartered accountants in the world [32]. The country's significant successes in human development are well known. However, it has still been recognized as a transitional economy by the academics and policymakers. Also, according to United Nations assessment, Sri Lanka is known as one of the least urbanized countries in the world. About 81.7% of the population of the country still lives in rural and plantation areas based on agricultural and agri-base related industry. Accordingly, the social and living condition of peoples is also significantly different between rural and urban areas in Sri Lanka [33]. Figure 2 displays the urban population scenario in the selected South Asian countries. The percentage of urban population is continuously increasing in Bangladesh, India, and Pakistan whereas Sri Lanka has witnessed a marginal decrease in its urban population. Sri Lankan urban population remained below 20% of total population between 1978 and 2014.

The statistics show that percentage of urban population of the country has marginally dropped in last three decades. According to the Asian population estimation of United nations, it is expected that in 2050, Asia is estimated to reach to at least 60% urban population. However, Sri Lanka is estimated to remain less than 40% urban population. Geographically, Sri Lanka is identified as Small Island with the tropical climatic condition. The official statistics indicate that global warming and climate change is taking place in the country in term of rainfall inconsistency and rising temperature [34]. The environmental degradation in terms of carbon emissions situation is being portrayed in the selected South Asian countries in Figure 3. Carbon emission per capita in Sri Lanka is higher than in Bangladesh over period from 1978 to 2014. This figure for Sri Lankan economy is reached to the level of carbon emissions in Pakistan in 2014. The carbon emissions continuously aggravated from 1993 to 2004 and from 2008 to 2014 for Sri Lanka.

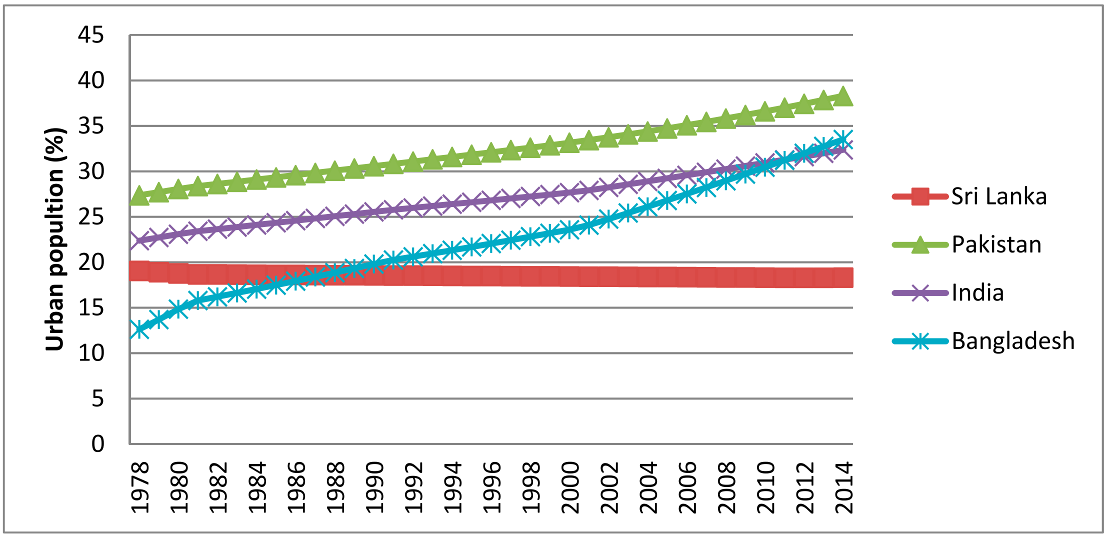

Figure 2. Urban population in selected South Asian countries.

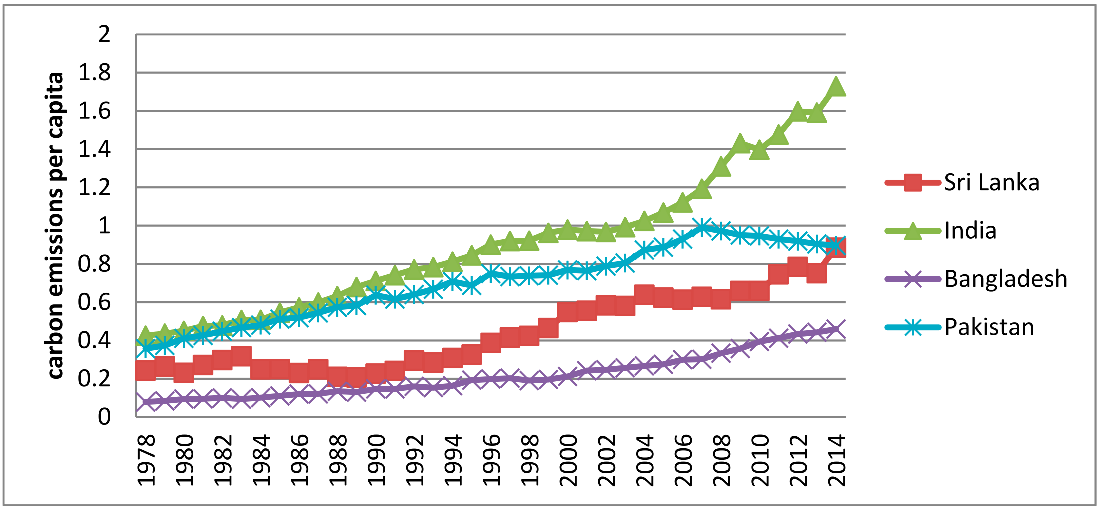

Figure 3. Carbon emissions per capita in selected South Asian countries.

Sri Lanka has recently been increasingly affected by different natural hazards. The level of carbon emission in the country is continuously rising which is one of the indicator of environmental degradation. Thus, in order to tackle environmental degradation, Sri Lanka national environmental action plan 1992–1996 was executed to establish an environmental protection plan within the context of development. Importantly, this national environmental action plan comprises of both corrective and preventive measures in areas such as industry pollution, energy, water and land resources, urban pollution, water and land resources, bio-diversity and wildlife, coastal resources, education and culture. However, despite of such plan, environmental degradation in the country has come to a peak as result of various socio-economic activities [3]. Therefore, environmental issues in Sri Lanka need attention from the researchers. Although some studies are carried in the past in this regard, for example, in a study, Uddin, Badisha and Ozturk [35] determined the effect of economic growth and energy consumption on carbon emissions in Sri Lanka. Likewise, the study of Gamage et al. [3] determined the impact of tourism development on carbon emissions along with energy in Sri Lanka. However, no study investigated yet the impact of urbanization and trade on carbon emissions in Sri Lanka. On the other hand, no similar study is found about the same phenomena in a context of island transitional economy where urbanization is a comparatively small proportion of the population in liberalized economic settings. Moreover, no study so far applied bounds tests with unknown structural break in case of Sri Lanka. Hence, this study is carried out to fill this gap in energy economics literature. Therefore, the main objective of this study is to explore the nexus between energy, trade, urbanization and environmental degradation in Sri Lanka.

The rest of this paper is organized as follows: Section 2 provides a literature review on the relationship between urbanization, trade, energy consumption and carbon emissions. Section 3 describes empirical model of the study, data, estimation strategy, and methods applied in the study. Empirical results are discussed in Section 4 of the study. Section 5 presents a discussion on the results of the study and Section 6 concludes the study and presents policy implications.

2. Literature Review

2.1. Economic Growth, Energy and Environmental Degradation

The nexus between economic growth and environmental degradation has been studied in the theoretical framework of the EKC hypothesis [36–38]. However, recent studies had mostly considered other relevant variables in the EKC framework. It is agreed that energy consumption is closely associated with economic growth and development. However, energy is not just responsible for the economic growth but it also garbs attention in the environmental economic literature as it may harm the environment. Thus, some of the studies analysed the casual relationship between energy, economic growth and carbon emissions. For instance, Soytas, Sari and Enwing [38] argued that energy consumption has some policy implication especially in mitigating environmental degradation thus; to find out the exact relationship and to address omitted variables problem it is very important to add energy consumption in the economic growth-emissions nexus. They deduced that energy consumption had played vital role in environmental degradation instead of income level in the US. In a similar way, Uddin, Badisha and Ozturk [35] studied the relationship between energy consumption, economic growth and carbon emissions in Sri Lanka. They considered carbon emissions as proxy for environmental degradation. The results of the study indicate there is long-term relationship among the studied variables and one-way causation is running from economic growth to energy consumption and carbon emissions.

Obradovic and Lojanica [39] carried out empirical study to examine the relationship between energy consumption, economic growth and carbon emissions in the case of Greece and Bulgaria. The results confirm no causality between energy consumption and growth in both Greece and Bulgaria in the short term; however, in the long term, causality runs from energy and carbon emission to GDP in both countries. Similarly, the study of Kais and Mbarek [40] investigated the causal relationship between economic growth, carbon emissions, and energy consumption in three selected North African countries from 1980 to 2012. The results show a unidirectional causality from GDP to energy consumption and from GDP to carbon emissions. The results furthermore confirm that there is a considerable interdependence between energy consumption and GDP in the long term. However, the findings of Lee and Yoo [41] study showed that there is a bidirectional relationship between economic growth and energy consumption and between energy consumption and carbon emissions while unidirectional causality runs from carbon emission to economic growth in Korea over the period from 1971 to 2008. Another recent study, Aye et al. [42] observed that economic development positively adds to carbon emissions in the high growth regimes while it indicates negative effect on carbon emissions in low growth regime. Besides, results of the study did not find the EKC hypothesis in 31 developing countries of Asia, Africa, and South America from 1971 to 2013. About the Sri Lanka case, Uddin et al. [35]

examined the long term association between energy consumption, economic growth, and carbon emissions using time series data from 1971 to 2006. The study has applied Granger causality and Johansen co-integration analysis tests and established a long term causal relationship between carbon emissions and economic growth. Moreover, the results confirmed unidirectional causality running from growth to energy consumption and carbon emissions. The aforementioned studies discussed in this section showed that energy consumption has positive impact on carbon emissions, but this is not always true, as some of the studies found that energy has a negative impact on carbon emissions [18].

2.2. Urbanization and Environmental Degradation

The impact of urbanization on environment can be positive or negative. The urbanization process may increase the commercial energy consumption and carbon dioxide emissions [13,14,43]. Using panel data for India, China, Indonesia, and Brazil from 1970 to 2012, the findings of a study by Alam et al. [44] revealed that there is a significant relationship between carbon emissions and population growth for India and Brazil, while it was statistically insignificant for Indonesia and China in both the short and long term. Some studies have studied the relationship between energy consumption, carbon emissions, economic growth and urbanization within a country-specific context. For China, Wang et al. [45] observed that urbanization level has a positive influence on carbon emissions in the western region, while urbanization did not significantly influence carbon emissions in eastern region, which has the most rapid urbanization development in China.

In the context of time series analysis, Shahbaz et al. [18] analyzed the impact of urbanization on carbon emissions in the UAE. They applied the bounds testing approach in the presence of structural break. The results of the study showed that there is long-term relationship between economic growth, electricity consumption, urbanization and carbon emissions in the UAE. Moreover, this study concluded that electricity consumption has a negative impact on carbon emissions, whereas urbanization has a positive effect on carbon emissions in the UAE. Similarly, Katircioglu and Katircioglu [19] examined the role of urbanization in environmental degradation for Turkey's economy. They considered urbanization impact on environmental degradation in the frame work of the EKC hypothesis. The results of the study indicated that rapid urbanization increases traditional energy consumption which positively affects carbon emissions. Also, the results of their study did not affirm the EKC hypothesis in Turkey.

2.3. Trade and Environmental Degradation

The study of Grossman and Krueger [10] is considered a pioneering work on the effects of trade on the environment. Trade liberalization affects pollution level through three separate mechanisms in the local economy. First, trade liberalization leads to increase in the economic activity, and if there is no change in the production technique, then trade will lead to enhanced pollution in the local economy. This effect of trade on pollution can be referred as scale effect. Similarly, the second effect of trade liberalization is referred to as the composition effect. Economies specialize in those sectors in which they have a competitive advantage. Therefore, trade liberalization enhances the intensive use of its abundant factors and henceforth, the net effect of trade on environmental pollution in local economy depends on whether trade liberalization expand or contract pollution-intensive activities. Finally, the technique effect of trade liberalization is very important in the belief that trade liberalization policies will put less pressure on the environment. The reason for this is that because of such policies, the local economy will experience a change in the production techniques as modern technologies shift from developed economies to less developed economies because of relaxation in foreign investment. Thus, the generation of pollution per unit of production falls in less developed economies.

Although trade is a vital determinant in the carbon emissions-energy-growth nexus, the question as to whether trade is beneficial for the environment or harmful to the environment is not settled in the empirical literature. The relationship among international trade, energy consumption, carbon emissions, and economic growth has involved many economics scientists [46–48]. Some studies have observed that trade openness might help to combat global warming [46]. The findings of the study conducted by Haq, Zhu and Shafiq [2] concluded that trade leads to lower carbon emissions in Morocco; hence, trade is beneficial for the environment. Similarly, in the Singapore context, Zambrano-Monserrate et al. [49] recently verified the Environmental Kuznets Curve (EKC) hypothesis by applying the ARDL model for period 1971–2011. The results showed an inverted U-shaped relationship between income and carbon emissions in both long and short term. Also, energy consumption has sound effects on carbon emissions in the long-run. The Granger causality test established that trade openness helps to reduce carbon emissions. There are some empirical studies whose results confirmed that trade is damaging the environment as it is responsible for increase in the carbon emissions. For instance, the study of Nasir and Reheman [1] confirmed that trade leads to increase in carbon emissions; thus, trade is responsible for environmental degradation in Pakistan. The findings of a study by Murad and Mazumder [50] confirm that there is no evidence of an inverted U-shaped EKC hypothesis for Malaysia. However, trade is damaging the environment. For Tunisia, Chebbi et al. [51] observed the association between income, trade openness, and carbon emissions by using the cointegration test. The results of the study confirmed that trade positively contributed to carbon emissions not only in the long term, but in the short term as well. Also, as observed in the study of Nguyen et al. [52], trade openness is a crucial factor of carbon emissions-energy-growth in China, but it does not provide evidence for the Indian economy.

3. Materials and Methods

3.1. Empirical Model of the Study

This study developed an empirical model closely following research performed by Nasir and Rehman [1], Haq et al. [2], Gamage et al. [3], Katircioglu and Katircioglu [19] and Uddin et al. [35]. The study carried out by Uddin et al. [35] determined the effect of energy and economic growth on carbon emissions while the study conducted by Gamage et al. [3] examined the effects of energy along with tourism on carbon emissions in Sri Lanka. Trade as a potential determinant of carbon emissions was treated in the studies of Nasir and Rehman [1] and Haq et al. [2], whereas Katircioglu and Katircioglu [19] examined the effect of urbanization on carbon emissions in the EKC hypothesis context. Thus, the following model was developed for our empirical analysis:

$$CEP_t = f(EC_t, PC_t, PC2_t, TO_t, URB_t) \tag{1}$$

The empirical model of the study implies that carbon emissions (CEP) are the function of energy consumption per capita (EC), per capita (PC), per capita squares (PC2), trade openness (TO) and urbanization (URB) in Sri Lanka. The model in Equation (1) can be rewritten in log-form as follows in Equation (2):

$$\log CE_t = \alpha_0 + \alpha_1 \log EC_t + \alpha_2 \log PC_t + \alpha_3 \log PC2_t + \alpha_4 \log TO_t + \alpha_5 \log URB_t + \mu_t \tag{2}$$

3.2. Variables, Data and Econometric Techniques

In this study, carbon emission (metric tons) per capita is used as a proxy for environmental degradation in Sri Lanka. Energy consumption is proxied by energy consumption per capita (kg of oil equivalent per capita), while income level is proxied by real GDP per capita. Trade openness is measured as the ratio of the exports plus imports to GDP. Urban population is used as a proxy for urbanization. Data on all these variables were gathered from World Development Indicators, World Bank online database. The period of the data is from 1978 to 2014. This is time series data, so the variables of the study have to be tested for the unit root, as time series data usually carries the unit root. However, we will apply the Zivot-Andrew (ZA) unit root test [53] instead of conventional unit root tests such as Augmented Dickey-Fuller unit root test [54] and Phillips-Perron test [55], as ZA also detects unknown structural break. Once the unit root properties of the time series data have been identified, along with structural break, we employ autoregressive distributed lag model (ARDL) to determine the cointegration in the time series. This test also acts as a bounds test. This model was developed by Pesaran et al. [56], and is a combination of autoregressive and distributed lag models. The great advantage of this model compared to other cointegration techniques is that it can be applied irrespective of the order of integration of the variables. Hence, it is not essential whether variables are integrated of order I (0) or I (1). However, it cannot be applied if variables are integrated of higher order than I (1). Correspondingly, the dependent variable has to be integrated of I (1), and for the rest of the variables, it does not matter whether their order of integration is I (0) or I (1), or combination of I (0) and I (1) [56]. This test has lower and upper bounds for critical values of F-statistics; if the computed F-statistic is greater than the upper bounds, then the corresponding model is cointegrated. The ARDL model for the current study in the presence of structural break can be written as in the following Equations:

$$\begin{aligned}\Delta\log CEP_t = \beta_0 + & \sum_{i=1}^{q1}\beta_1\Delta\log CEP_{t-i} + \sum_{i=0}^{q2}\beta_2\Delta\log EC_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log PC_{t-i} \\ & + \sum_{i=0}^{q3}\beta_3\Delta\log PC2_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log TO_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log URB_{t-i} \\ & + \gamma_1\log CEP_{t-1} + \gamma_2\log EC_{t-1} + \gamma_3\log PC_{t-1} + \gamma_4\log PC2_{t-1} \\ & + \gamma_5\log TO_{t-1} + \gamma_6\log URB_{t-1} + \vartheta_D D_1 + \mu_t\end{aligned} \tag{3}$$

$$\begin{aligned}\Delta\log EC_t = \beta_0 + & \sum_{i=1}^{q1}\beta_1\Delta\log CEP_{t-i} + \sum_{i=0}^{q2}\beta_2\Delta\log EC_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log PC_{t-i} \\ & + \sum_{i=0}^{q3}\beta_3\Delta\log PC2_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log TO_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log URB_{t-i} \\ & + \gamma_1\log CEP_{t-1} + \gamma_2\log EC_{t-1} + \gamma_3\log PC_{t-1} + \gamma_4\log PC2_{t-1} \\ & + \gamma_5\log TO_{t-1} + \gamma_6\log URB_{t-1} + \vartheta_D D_2 + \mu_t\end{aligned} \tag{4}$$

$$\begin{aligned}\Delta\log PC_t = \beta_0 + & \sum_{i=1}^{q1}\beta_1\Delta\log CEP_{t-i} + \sum_{i=0}^{q2}\beta_2\Delta\log EC_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log PC_{t-i} \\ & + \sum_{i=0}^{q3}\beta_3\Delta\log PC2_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log TO_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log URB_{t-i} \\ & + \gamma_1\log CEP_{t-1} + \gamma_2\log EC_{t-1} + \gamma_3\log PC_{t-1} + \gamma_4\log PC2_{t-1} \\ & + \gamma_5\log TO_{t-1} + \gamma_6\log URB_{t-1} + \vartheta_D D_3 + \mu_t\end{aligned} \tag{5}$$

$$\begin{aligned}\Delta\log PC2_t = \beta_0 + & \sum_{i=1}^{q1}\beta_1\Delta\log CEP_{t-i} + \sum_{i=0}^{q2}\beta_2\Delta\log EC_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log PC_{t-i} \\ & + \sum_{i=0}^{q3}\beta_3\Delta\log PC2_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log TO_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log URB_{t-i} \\ & + \gamma_1\log CEP_{t-1} + \gamma_2\log EC_{t-1} + \gamma_3\log PC_{t-1} + \gamma_4\log PC2_{t-1} \\ & + \gamma_5\log TO_{t-1} + \gamma_6\log URB_{t-1} + \vartheta_D D_4 + \mu_t\end{aligned} \tag{6}$$

$$\begin{aligned}\Delta\log TO_t = \beta_0 + & \sum_{i=1}^{q1}\beta_1\Delta\log CEP_{t-i} + \sum_{i=0}^{q2}\beta_2\Delta\log EC_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log PC_{t-i} \\ & + \sum_{i=0}^{q3}\beta_3\Delta\log PC2_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log TO_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log URB_{t-i} \\ & + \gamma_1\log CEP_{t-1} + \gamma_2\log EC_{t-1} + \gamma_3\log PC_{t-1} + \gamma_4\log PC2_{t-1} \\ & + \gamma_5\log TO_{t-1} + \gamma_6\log URB_{t-1} + \vartheta_D D_5 + \mu_t\end{aligned} \tag{7}$$

$$\begin{aligned}\Delta\log URB_t = \beta_0 + & \sum_{i=1}^{q1}\beta_1\Delta\log CEP_{t-i} + \sum_{i=0}^{q2}\beta_2\Delta\log EC_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log PC_{t-i} \\ & + \sum_{i=0}^{q3}\beta_3\Delta\log PC2_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log TO_{t-i} + \sum_{i=0}^{q3}\beta_3\Delta\log URB_{t-i} \\ & + \gamma_1\log CEP_{t-1} + \gamma_2\log EC_{t-1} + \gamma_3\log PC_{t-1} + \gamma_4\log PC2_{t-1} \\ & + \gamma_5\log TO_{t-1} + \gamma_6\log URB_{t-1} + \vartheta_D D_6 + \mu_t\end{aligned} \tag{8}$$

where Dummy (D_i) represents unknown structural break and μ_t presents the disturbance term in each equation. The null hypothesis has to be tested ($\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = 0$) that there is no long-term relationship among the variables against the alternative hypothesis ($\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq 0$, which confirms the long-term relationship.

Ordinary least squares (OLS) gives biased estimates if regressors are integrated of order one. However, we have fully modified ordinary least squares (FMOLS), which is suitable in such cases when variables become stationary on first difference and variables of the study are cointegrated. This was developed by Phillips and Hansen [57]. This technique has several advantages over other cointegration techniques. This technique provides estimates free from the problems of endogeneity and autocorrelation, so the estimates are efficient and unbiased. For the classical polynomial regression, the OLS estimates are consistent but have a second-order bias. To overcome this problem, a fully modified OLS (FM-OLS) estimation is suggested. For this purpose, the considered dependent variable under this technique is modified in the following way:

$$y_t^+ = y_t - v_t'\hat{\omega}_{vv}^{-1}\hat{\omega}_{vv} \text{ and } y^+ = \left[y_1^+, y_2^+, \ldots, y_T^+\right]'$$

It is assumed that v_1 is known in advance and in applications of $x_1, x_2, \ldots, x_T$ only $v_2, \ldots, v_T$ will be computed, where $t = 2, 3, \ldots, T$.

$$M^* = \begin{bmatrix} M_1^* \\ M_2^* \\ . \\ . \\ . \\ M_m^* \end{bmatrix}, M_j^* := \hat{\gamma}_{v_j u}^+ \begin{bmatrix} 2\sum^{T} x_{jt} \\ . \\ . \\ . \\ p_j \sum x_{jt}^{p_j - 1} \end{bmatrix} \tag{9}$$

where $\hat{\omega}_{vv}$, $\hat{\gamma}_{v_j u}$ and $\hat{\gamma}_{v_j u}^+ := \hat{\gamma}_{v_j u} - \hat{\omega}_{vv}\,\hat{\omega}_{vv}^{-1}\,\hat{\gamma}_{v\ v_j}$.

Now, $\hat{\beta}^+ = (X'X)^{-1}X'y^+ - A^*$, with

$$A^* = \begin{bmatrix} 0_{(q+1)X1} \\ M^* \end{bmatrix} \tag{10}$$

4. Results of the Study

The unit root properties of all the time series are given in Table 1. The third and last column represent the structural break in the respective series. The determination of structural break in the time series is very important for accurate evaluation of any plan intended to bring about structural change in the economy. For instance, if we consider the structural break of carbon emissions, energy and urbanization, then it seems that the Sri Lanka national environmental action plan 1992–1996 is responsible for these structural breaks. The aim of this plan was to establish an environmental protection plan within the context of development. This plan provides the guidelines for specific actions in those sectors which pollute the environment. Importantly, this plan also provides guidelines for determining the required time frame and investment level needed in specific sectors to reduce environmental pollution. This national environmental action plan comprises of both corrective and preventive measures in areas such as industry pollution, energy, water and land resources, urban pollution, water and land resources, bio-diversity and wildlife, coastal resources, education and culture. The results of the ZA unit root test show that all variables are non-stationary at level and become free from non-stationarity at their first difference. It can be deduced from these results that none of the variables are integrated of higher orders than one. Thus, we can apply a bounds test of cointegration with structural break.

The results of the bounds cointegration test with respective structural break is given in Table 2. This test confirmed that there are five cointegration vectors, as the calculated F-statistic of the bounds test is greater than the upper critical value. One can claim on the basis of these results that the variables of the study are cointegrated in the long term and were in a long-term relationship over the period of the study. Therefore, we can proceed to cointegration technique to obtain long-run estimates for the specified empirical model of the study.

Table 1. Unit root results with structural break.

Variable	ZA t-Stat.	Structural Break	Variable	ZA t-Stat.	Structural Break
log*CEP*	−3.73	1996	Δlog*CEP*	−8.03	1990
log*EC*	−3.25	1991	Δlog*EC*	−6.71	1996
log*PC*	−2.08	1987	Δlog*PC*	−5.21	2003
log*PC*2	−1.64	1987	Δlog*PC*2	−5.25	2003
log*TO*	−2.814	2008	Δlog*TO*	−5.91	1987
log*URB*	−1.13	1997	Δlog*URB*	−6.73	1994

Source: Authors' calculations.

Table 2. Results of bounds cointegration test.

Estimated Models	Structural Break	F-Stat.	Conclusion
Equation (3)	1996	3.48	Cointegrated
Equation (4)	1991	8.50	Cointegrated
Equation (5)	1987	33.23	Cointegrated
Equation (6)	1987	35.73	Cointegrated
Equation (7)	2008	2.06	Not Cointegrated
Equation (8)	1997	7.16	Cointegrated

Source: Authors' calculations.

Once it had been confirmed that variables of the empirical model of the study are cointegrated in the long term, we applied the FMOLS for the long-term estimates. The results of FMOLS are given in Table 3. All the explanatory variables are significant. Energy consumption was found to be significant, with a positive effect on carbon emissions. Hence, energy consumption deteriorated the environmental degradation in Sri Lanka during the study period. The coefficient of per capita income is negative and significant, while the coefficient of per capita squares is positive and significant; thus, there is U-shaped relationship existing between environmental degradation and income level in Sri Lanka. Therefore, it is deduced that the EKC hypothesis does not prevail in Sri Lanka. Trade openness positively contributed to carbon emissions, as its coefficient was significant with a positive sign. Therefore, foreign trade in Sri Lanka is not environmentally friendly. The results regarding urbanization in Sri Lanka are very interesting, as urbanization was significant with a negative sign. This finding of the study shows that urbanization in Sri Lanka is not responsible for the accumulation of carbon emissions. Thus, urbanization does not aggravate environmental degradation.

Table 3. Long term estimates.

Dependent Variable: log*CEP*				
Regressors	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
log*EC*	1.618222	0.161881	9.996346	0.0000
log*PC*	−8.811837	1.817011	−4.849633	0.0000
log*PC*2	0.653741	0.112424	5.814971	0.0000
log*TO*	0.658351	0.058800	11.19645	0.0000
log*URB*	−1.680952	0.545094	−3.083784	0.0045
Constant	0.918843	0.038952	23.58881	0.0000
Dum	44.22906	3.745747	11.80781	0.0000

Source: Authors' calculations.

The results of the error correction model (ECM) are presented in Table 4. Energy consumption had a significant and positive effect on carbon emissions, like in the long term. Thus, energy consumption does not just contribute to environmental degradation in the long term, but in the short term as well. The coefficient of per capita income and its squares are insignificant in the short term; thus, the EKC hypothesis does not even prevail in the short term in Sri Lanka. Trade openness came out with a significant negative effect on carbon emissions; therefore, foreign trade does not hurt environmental quality in the short term. The coefficient of error correction term is negative and significant, which suggests that the model is in equilibrium and the model will get back into equilibrium from any external shock in less than two years.

Table 4. Results of ECM.

Dependent Variable: Δlog*CEP*				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
Constant	0.084013	0.063505	1.322930	0.1966
Δlog*EC*	1.030482	0.408627	2.521818	0.0176
Δlog*PC*	5.398772	6.594151	0.818721	0.4199
Δlog*PC*2	−0.355499	0.422867	−0.840688	0.4076
Δlog*TO*	0.247078	0.185126	1.334648	0.1927
Δlog*URB*	−7.054173	4.154252	−1.698061	0.1006
Dum	0.030261	0.089625	0.337643	0.7382
ECT(−1)	−0.661063	0.189424	−3.489858	0.0016

Source: Authors' calculations.

5. Results Discussion

This study found a long-term relationship among carbon emissions, energy consumption, income level, trade openness and urbanization in the long term in Sri Lanka. The results of this study show that energy consumption aggravated the environmental degradation in Sri Lanka during the study period. Our results concerning energy consumption are consistent with earlier studies, for instance, the study of Gamage et al. [3], who also found a significant positive effect of energy consumption on environmental degradation in Sri Lanka. The energy from fossil fuel was 27% in 1978 compared to 50% in 2014; thus, energy from fossil fuels has increased. The share of coal in total energy was negligible in 1990, whereas its share reached almost 10% in 2014. Similarly, Sri Lanka experienced an increase of coal share in electricity generation from 9% to above 25% during 2011–2014. The share of renewable energy in total energy consumption was slightly above 78% in 1990, whereas this share remained around 57% in 2014. This means that Sri Lanka experienced a decrease in energy from renewable resources, and as a result, energy in Sri Lanka is responsible for environmental degradation. Sri Lanka can upset the effect of energy from non-renewable resources by increasing the share of energy from renewable resources. Sri Lanka is among the most ideal settings for hydropower in South Asia [58]. The country's electricity generation is mainly dependent on hydropower. The government is targeting an energy self-sufficient country by 2030. However, climate change has had an adverse effect on the hydroelectricity generation capacity of the country in recent years. Sri Lanka, a tropical nation, is highly vulnerable to the impacts of climate change. Thus, policymakers of the country have to consider the concept of the Green Economy as a key strategy to tackle the hazards of climate change [34].

The results of this study revealed that the EKC hypothesis does not prevail in Sri Lanka in the long term or in the short term. This means that the Sri Lankan economy did not reach the income level beyond which further increase in income level results in a lower level of carbon emissions. This implies that increase in income level is not followed by a lower level of emissions. This finding of the study is consistent with earlier research studies, such as Gamage et al. [3], whose study also did not confirm the EKC hypothesis in Sri Lanka. Our results are also consistent with the findings of Haq et al. [2], whose study did not confirm the EKC hypothesis in Morocco. The results of this study show that trade openness contributes to environmental degradation in the long term. This result is consistent with Cole et al. [59] and Nasir and Rehman [1]. The main sectors of the Sri Lankan economy are tourism, tea export, textile and apparel products, rice and other agricultural products. However, the positive impact of trade on environmental degradation can be on the basis of scale, technique and the composite effects of trade. The scale effect might enhance carbon emissions, as greater exports expand the economic size of the country. This further explains that domestic investors in Sri Lanka did not use environment friendly technology. Additionally, imported technology in the form of machinery is not environmentally friendly. This indicates that Sri Lankan foreign trade is not environmentally friendly, but we are not sure whether this is due to the exports of the country, or if imports are responsible for this positive impact on environmental degradation, so it is recommended to consider exports and imports as factors of environmental degradation in future studies.

The results of this study indicated that urbanization does not lead to environmental degradation in Sri Lanka, as the coefficient of urbanization is significantly negative. This result of the study is consistent with Fan et al. [25] and Sharma [26], who found a negative correlation between urbanization and carbon emissions in developing countries. Similarly, Hossain [60] also confirmed that urbanization has a negative effect on carbon emissions in the long term. This conclusion of the study also supports the ideas of Capello and Camagni [30] and Tupy [27], who argued that urbanization leads to lower environmental damage in society, as it improves the public facilities. Another reason for this finding is the fact that there has been a decrease in the percentage of the urban population in Sri Lanka in the last two decades. Additionally, Sri Lanka has tropical climate conditions; thus, urbanization may not intensify the energy consumption, as urbanization does not lead to the accumulation of carbon emissions in the atmosphere of the Small Island. Another fact about the negative association between urbanization and carbon emissions is that the human development index in Sri Lanka is high as compared to the South Asian region. This means that the Sri Lankan government is being successful in providing necessities even in rural areas, resulting in a less urbanized population.

6. Conclusions

Sri Lanka has recently been increasingly affected by different natural hazards. The level of carbon emission in the country is continuously rising, which is one of the indicators of environmental degradation. Thus, in order to tackle environmental degradation, the Sri Lanka national environmental action plan 1992–1996 was executed to establish an environmental protection plan within the context of development. Importantly, this national environmental action plan consists of both corrective and preventive measures in areas such as industry pollution, energy, water and land resources, urban pollution, water and land resources, bio-diversity and wildlife, coastal resources, education and culture. However, in spite of the existence of such a plan, environmental degradation in the country has come to a peak as a result of various socio-economic activities. Therefore, environmental issues in Sri Lanka need attention from researchers.

This study was conducted to examine the nexus between energy, trade, urbanization and environmental degradation in the context of the EKC hypothesis for Sri Lanka. For this purpose, we analyzed the time series data, and the unit root problem was checked, along with structural breaks. The long-term relationship was determined through the bounds testing approach, among the variables of the study. This study found that energy positively contributed to carbon emissions, so it is among the leading causes of environmental degradation in Sri Lanka. The results show that there was a U-shaped relationship between income and environmental degradation, opposite to what the EKC hypothesis would present. This means that the Sri Lankan economy is achieving economic growth at the expense of extensive use of resources, thereby depleting the natural environment. The results show that foreign trade contributes positively to environmental degradation, as it has positive and significant effect on carbon emissions. The long-term estimates regarding urbanization show that urbanization is not responsible for the emissions of carbon in the environment; instead, its effect on environmental degradation is negative. This finding proves that urbanization is not harmful for the environment in Sri Lanka and supports the idea that urbanization brings efficiency in public facilities such as public transport and electricity. Another reason for the negative effect of urbanization on carbon emissions is that under the Sri Lanka national environmental action plan 1992–1996, the government affirms the concerns regarding urban pollution and energy use, along with water and land use. Therefore, the government reserved the forest area, and hence, urbanization was marginally reduced over the period in Sri Lanka. Steps are required from the government to ensure the present behavior of the people in urban areas, especially regarding energy consumption and construction under which they have to keep open areas for plantation. Also, the government has to ensure energy efficiency in urban development in future. Strict measures should be taken to make the production process environmentally friendly. Additionally, the government has to move forward towards the green economy concept. Awareness of the masses through media and encouraging conferences about sustainable development will help the government to adopt the concept of green economy. Similarly, the government can ensure sustainability goals through nurturing cooperation between private and public sectors by sharing information on financing strategies for energy-saving technology transfer processes. This study recommends adopting the measures required to make trade beneficial for the environment. This is only possible by implementing environmentally friendly measures in domestic production processes and taking measures to make imports more environmentally friendly. It is suggested for future research that, in order to understand the relationship between environmental degradation and urbanization in Sri Lanka, other important variables such as household size and population density be considered in this nexus.

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