Analysis of urbanization and energy consumption using time series data: Evidence from the SAARC countries

Abstract

Urbanization has posed some tremendous challenges which are related to environmental stresses through increased energy consumption. These challenges have drawn attention to the need to implement urbanization with sustainable energy consumption globally. The present study aims to identify the urbanizing factors that cause energy consumption in the SAARC countries. The South Asian Association for Regional Cooperation is considered in the study during the period of 1975-2014. The data are analyzed by using simple statistics and econometric techniques, such as the ordinary least squares (OLS) method for the country level. The study has found that all urbanizing variables significantly affect energy consumption with different levels in different countries, as shown by the OLS method. The coefficient of GDP is statistically significant at 1% level of significance for Bangladesh, Pakistan and Sri Lanka, while at 5% and 10% levels for India and Nepal, respectively. The coefficient of the industrial sector share in GDP is statistically significant at 1% level of significance for Bangladesh, Nepal and Pakistan. The result shows that a 1% increase in the service sector's share in GDP leads to a reduction in energy consumption of 0.15%, 0.34% and 1.61%, respectively, in Bangladesh, Nepal and Sri Lanka. The result for urban population indicates that a 1% increase in urban population leads to an increase in energy consumption by 1.94%, 2.32%, 0.85% and 3.87%, respectively, for Bangladesh. India, Nepal and Sri Lanka. Green technology and energy efficiency technologies to use in the industries, encourage using public transportation, sustainable energy and urbanization are potential policy recommendations.

Keywords: Energy consumption, Urban population, Population density, The SAARC countries.

1. Introduction

Urbanization and energy consumption are two aspects of modern economies with high potential to impact sustainable development (Zaharia, Diaconeasa, Brad, Lădaru and Ioanăș, 2019). Urbanization is a demographic process where an increasing share of the national population lives within urban settlements (Arouri, Youssef, Nguyen-Viet and Soucat, 2014; Rahman, 2019). Urbanization and economic development are related, and the concentration of city resources like labor and capital is a part of this process (Rahman, 2019). Rahman (2019) explained that urbanization is considered as the engine for economic growth as well as economic development, as 80% of the economic output originates in the urban regions where energy has a vital role to play. Energy is crucial for economic development in any country and an essential component for improving the socio-economic conditions, getting education, raising income, improving life-styles and so on (Anker-Nilssen, 2003; Mahadevan and Asafu-Adjaye, 2007; Rehman and Rashid, 2017). In recent decades, economic growth has led to a significant increase in energy consumption, and the energy demand has increased annually by 39% on average in the world (Mrabet, Alsamara, Saleh and Anwar, 2019, p. 832).

Urbanization leads to a series of challenges in natural resources and the ecological environment (Wu, Haob and Weng, 2019). According to the International Energy Agency (IEA) 2015, global energy resources supply consist mainly of natural gas (24%), coal (27%), oil (36%), hydro (6%), nuclear (6%) and renewable energy (about 1%), that means more than 80% of these energy resources are fossil fuels (Mrabet et al., 2019, p. 832). The consumption of energy in urban areas has significantly created an alarming situation for environmental degradation, especially the fossil-fuels-based energy use (Afridi, Kehelwalatenna, Naseem and Tahir, 2019; Wu, Haob and Weng, 2019). In addition, urbanization is a global phenomenon and an important factor for any country's growth process that requires immense energy sources but is also a threat to global warming and degradation of the environment (Abbasi, Parveen, Khan and Kamal, 2020).

It is predicted that 68% of the world's population will be urban citizens by 2050, much of which will occur in Africa and Asia, notably in the SAARC countries, which will add 20% more city dwellers by this period (UN, 2019). According to the International Monetary Fund (IMF) data, South Asia has represented 3% of the world's area, 21% of the world's population and 3.8% of the global economy, as of 2015 (SAARC, 2015). Additional urban infrastructure is needed to support the unprecedented growth of these countries, so it is a cause for more resource consumption, exerting additional pressure on the already fragile ecosystems of these countries (Cetin, Ecevit and Yucel, 2018; Wang et al., 2016). However, this region faces a threat of energy security, as it has not only a limited capacity of energy resources, mainly nonrenewable sources, but is also subject to/challenged by the volatile and higher prices of energy, urbanization, and population growth (Ahmad and Majeed, 2019). In addition, the use of mostly nonrenewable sources of energy is one of the main causes of carbon dioxide emissions and environmental degradation in the area (Afridi et al., 2019; Ahmad and Majeed, 2019).

In addition, national economic development policy focuses on getting better quality of life for its citizens without reducing the energy resources of the country in this region (that is related to SDG Goal 7- affordable and clean energy) (UN, 2015). This study aims to examine how urbanization affects energy consumption in the SAARC countries. The study deals the impact of urbanization on energy consumption for the country level. It analyses time series aggregate data, both for trend in urbanization and energy use, and to identify the urbanization factors influencing consumption of energy at the national level.

2. Overview of the Literature

The majority of previous studies in different countries have shown that urbanization has a direct impact on energy consumption. For example, Parikh and Shukla (1995), Zhao and Zhang (2018), identified three main reasons why urbanization increases energy use per capita: demand for industries and infrastructure; demand for transportation; and household demand to increase the quality of life. It is a common phenomenon to see an upward energy demand for urbanization from developed to developing economies. Urban households consume 50% more energy than rural households per capita, which indicates that continued urbanization will promote the growth of national energy consumption (Zhao and Zhang, 2018). More importantly, the increased use of personal transportation is another cause for the rising energy usage (Parikh and Shukla, 1995; Salim and Shafiei, 2014). A large urban population represents a larger labor force for large-scale production, but inputs must be assembled from greater distances, and products must be sold over larger market areas, and this will have a positive effect on energy use through increasing use of different transport modes (Jones, 1991). Another important reason is that a higher household income can ensure higher quality lifestyles; this makes the demand for energy to increase in the urban areas (Chikaraishi et al., 2015).

Other studies have argued that urbanization could lead to a decrease in energy resources available (Ewing and Rong, 2008; Lariviere and Lafrance, 1999; Lin and Ouyang, 2014). They have argued that urbanization has led to lower per capita energy consumption through energy efficiency, mostly in developed countries like Canada, and the USA (Ewing and Rong, 2008; Lariviere and Lafrance, 1999). Lin and Ouyang (2014) also agreed with this statement by using the Environmental Kuznets Curve. They have found an inverted U-shaped relationship between energy demand and economic growth in the long run. Energy consumption increased as urbanization increased in the early stages, then, after energy consumption reached a peak level, an increase in urbanization was related to a decline of energy use. This was largely attributed to the enhancement of energy efficiency. Similarly, Poumanyvong and Kaneko (2010); Yassin and Aralas (2019) explained that urbanization could lead to an increase in social awareness and the economies of scales for urban public infrastructure to protect the environment by the ecological modernization theory. This theory argued that urbanization is a process of social restructuring which has encouraged a structural change from an industrial to a service-based economy and has indirectly reduced the negative impact on the environment (Poumanyvong and Kaneko, 2010; Yassin and Aralas, 2019).

Sadorsky (2013) explained that energy intensity tends to highly correlated with developed countries than developing countries but income, urbanization and industrialization etc. affect energy intensity also. As a result, it is difficult to measure to the impacts of urbanization on energy intensity because on the one side, urbanization increases energy consumption through increase of consumption and production; it leads to increase in energy efficiency through economies of scale on the other side (Sadorsky, 2013).

A study by Azam, Khan, Zaman and Ahmed (2015) has found that urbanization growth has a significantly positive effect on energy consumption. Similarly, Gasimli et al. (2019) showed that there is long-term relationship between energy consumption, trade, urbanization and carbon emissions in Sri Lanka. However, the increasing density of the urban population causes the deterioration of air quality due to, for instance, the increase in electricity consumption, the number of automobiles, and the loss of tree cover as a result of urban development (Mulali, Ozturk and Lean, 2015).

Besides, the growth of urbanization in developing countries is higher compared to developed countries (Behera and Dash, 2017). Energy demand is expected to be affected dramatically by the growth and density of urban areas in developing countries. Some studies have investigated the impacts of urbanization on energy consumption in developing countries or regions (Bakirtas and Akpolat, 2018; Behera and Dash, 2017; Ewing and Rong, 2008; Jones, 1991; Parikh and Shukla, 199; Wu et al., 2019; Zhang and Zhao, 2016; Zhao and Zhang, 2018).

Rapid urbanization has posed some tremendous challenges which are related to environmental pressures, due to energy consumption (Zhang and Lin, 2012), and these challenges have drawn global attention. A similar study by Afridi et al. (2019) in the SAARC countries, pointed out that more than 20% of the world's population lives in this region, and the average urban population in these countries represents 34%. However, the urban population grew by 130 million over the period 2001 to 2011 and it is expected to rise by almost 250 million by 2030 in this region. The growth has led to an increase in the demand for energy that depends on traditional energy sources.

However, half of the world population is living in urban areas, and urban cities consumed more than 50% of the overall energy and produced over 60% carbon dioxide (CO_2) emissions, which contributes to global warming (IEA, 2012; Shahbaz, Loganathan, Sbia and Afza, 2015, p. 683). Meanwhile, CO_2 emissions are rapidly increasing from developing countries, especially from China, India, and the ASEAN (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand, and Vietnam) region since 2005; these countries accounted for almost 50% of the world's CO_2 emissions (Shahbaz et al., 2015, p. 684; WDI, 2012).

Zhu and Peng (2012) referred to three different channels through which urbanization affects CO_2 emissions. First, an increase in the city's population will increase residential consumption and energy demand, thereby producing a surge in CO_2 emissions. Second, urbanization generally boosts demand for housing and naturally raises the demand for housing material, which is known as the major source of CO_2 emissions. Thirdly, the clearing of trees and grassland activities, as demand for housing will increase, which determine emission of the carbon stored in the trees. Therefore, urbanization has posed some tremendous challenges which are related to environmental stresses, through increased energy consumption (Zhang and Lin, 2012). These challenges have drawn global attention to the need of implementing urbanization with sustainable energy consumption in the world. As the above arguments indicate, more empirical analyses from different contexts are required in order to be able to generalize existing knowledge of the effects of urbanization on energy use.

3. Methodology

3.1 Study area and data source

The South Asian Association for Regional Cooperation (SAARC) provides a platform for the peoples of South Asia. There are seven founder members, namely Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka, in this association established in 1985, and Afghanistan joined in 2005 (SAARC, 2007). According to International Monetary Fund (IMF) data, this region represents 3% of the world's area, 21% of the world's population and 3.8% of the global economy, as of 2015 (SAARC, 2015). According to number of population India is the first largest country in this region followed by Pakistan, Bangladesh, Afghanistan, Nepal, Sri Lanka, Bhutan and Maldives (SAARC, 2015). In this study we compared the relationship between urbanization and energy consumption in five selected SRRAC countries (i.e., Bangladesh, India, Nepal, Pakistan and Sri Lanka) by using national-level secondary data (Appendix A). These countries are selected because of not only availability of data but also their vital importance to an emerging region like SAARC. The data collected from the World Development Indicators database (WDI) 2016 during the period of 1975 to 2014.

3.2 Estimation method

The multiple linear regression model is used in order to identify the effects of urbanizing variables on energy consumption for the SAARC countries. The GDP per capita, the share of the industry sector in GDP, the share of the service sector in GDP, urban population growth rate and urban population are the explanatory variables, as urbanization factors, and total energy use is the dependent variable in this study. The application of any regression model requires the time series of the concerned variables to be stationary which means that the mean and variance of each variable do not vary systematically over time (Shahbaz et al., 2013; Hocaoglu and Karanfil, 2013; Ozturk and Acaravci, 2013). In addition, there are three steps to estimate multiple linear regression using time series data as follows.

3.2.1 Unit root test

It is necessary to examine whether the time series of the variables are stationary before performing the regression analysis. (Gujrati 2004; Ozturk and Acaravci, 2013). The Augmented Dickey–Fuller (Dickey and Fuller, 1979) (ADF) test is employed to examine unit roots for stationarity (Munir and Khan, 2014), and determine the order integration of the variables in country by country basis. For this, the ADF test requires the equation as follows:

$$\Delta X_t = \alpha_o + \beta X_{t-1} + \delta_{1t} + \sum_{i=1}^{m} \mu_i \, \Delta X_{t-i} + \epsilon_t$$

Where t is the trend variable, ϵ_t is a pure white noise error term and $\Delta X_{t-1} = (X_{t-1} - X_{t-2})$, $\Delta X_{t-2} = (X_{t-2} - X_{t-3})$ and so on. The test for a unit root has the null hypothesis that $\beta = 0$. If the coefficient is statistically different from 0, the hypothesis that $X_t$contains a unit root is rejected.

3.2.2 Co-integration test

The next step is cointegration test that is testing hypotheses concerning the relationship between variables when they are nonstationary (Ahmad and Majeed, 2019; Chary and Bohara, 2010; Munir and Khan, 2014; Wang, Kang,Wang and Xu, 2017; Zeb, Salar, Awan, Zaman and Shahbaz, 2014). For instance, if two or more series are themselves non-stationary, but a linear combination of them is stationary, then the series are said to be cointegrated (Chary and Bohara, 2010; Munir and Khan, 2014). More importantly, regression analysis is said to be done best, by linear and by ordinary least squares method, with the help of a cointegration test (Munir and Khan, 2014). We employed Johansen's procedure to test for cointegration between the two series. The Johansen tests are on the rank of the coefficient matrix Π of the equation Johansen and Juselius (1990) and have the following form:

$$\Delta x_t = \Gamma_1 \Delta x_{t-1} + \cdots + \Gamma_{k-1} \Delta x_{t-k+1} + \Pi X_{t-k} + \mu + \epsilon_t$$

The null hypothesis for r cointegrating vector is

H_0: Π has a reduced rank, r<k

Where X_t is a k*1 vector of I (1) variables of $\Gamma_1 \ldots \ldots \Gamma_{k-1}$. Π is k*k matrices of unknown parameters, and the coefficient matrix contains information about the long-run relationship. The reduced rank condition implies that the process Δx_t is stationary and x_t is non-stationary. The presence of distinct cointegrating vectors can be obtained by determining the significance of the characteristics roots of Π. We use both the trace test and the maximum eigenvalue test to determine the significance of the number of characteristic roots that are not different from unity. The critical values for these tests are tabulated in Johansen and Juselius (1990).

3.2.3 Ordinary least squares (OLS) method

If cointegration tests are satisfied and all the variables are cointegrated, the next step to find the parameters of all the selected variables. The study employed the OLS method to find the regression estimation because of its simplicity and popularity (Ozturk and Acaravci, 2013). The relationship between a dependent variable (Y) and an independent variable (X) can be postulated as a linear regression (Gujrati, 2004, p. 58-62):

$$Y = \beta_0 + \beta_1 X + u$$

where β_0 and β_1 are regression coefficients and parameters while u is an error term. The estimated least squares regression is given by

$$\bar{Y} = \hat{\beta}_0 + \hat{\beta}_1 \bar{X}$$

This is known as simple linear regression which is used to estimate coefficients for the equation. For multiple linear regression with n explanatory variables (X_1…….. X_n), the estimated least squares regression is written as follows:

$$\bar{Y} = \hat{\beta}_0 + \hat{\beta}_1 \bar{X}_1 + \cdots + \hat{\beta}_n \bar{X}_n$$

3.3 Model specification

In order to analyze the link between energy usage and urbanization variables in selected SAARC countries, a multivariate framework based on the concept of the energy-urbanization nexus is used (Mudakkar et al., 2013; Shahbaz, Hye, Tiwari and Leitão, 2013). The energy consumption 'EC' as a function of urbanization 'U' reads

$$EC_t = F[U_t] \qquad (1)$$

where "F" is a linear homogenous function and 't' the time index. The two core components of urbanization are population urbanization (PU) and economic urbanization (EU) (Wang, Zeng, Huang, Shi and Zhan, 2018). Economic urbanization is assessed using three variables: per capita GDP (GDP), the industrial share of GDP (SIG), and the service share of GDP (SSG). However, indices of population urbanization include the urban population (UP) and the urban population growth rate (UPG) (Wang et al., 2018). In order to perform a thorough data analysis, this study attempted to include urban population, urban population growth rate, per capita GDP, industrial and service sector's share of GDP, and urban population as indicators in the energy function (Based on equation 1). In light of this expansion, the energy usage function may be written as follows:

$$EC_t = f(GDP_t, SIG_t, SSG_t, UP_t, UPG_t) \qquad (2)$$

In this study, we transform all the series into logarithms to attain direct elasticities. The model for the empirical equation is as follows:

$$lnEC_{it} = \beta_0 + +\beta_{1i} lnGDP_{it} + \beta_{2i} lnSIG_{it} + \beta_{3i} lnSSG_{it} + \beta_{4i} lnUP_{it} + \beta_{5i} lnUPG_{it} + \epsilon_{it} \qquad (3)$$

where β_0 and ϵ_{it} represent $\ln(B_0)$ and error term respectively of the ith country at t time respectively. Most importantly, $\beta_{1,} \dots \dots \dots \dots \dots \dots, \beta_{5,}$ represent the long-run elasticities of the dependent variable with respect to the independent variables. It is hypothesized that the coefficients signs of all the explanatory variables are expected to be positive. The description of the variables is provided in Table 1.

Table 1: Description of the Variables

Variable	Label	Definition	Unit of Measurement
Energy consumption	EU	Per capita electric power consumption	Per capita Kwh
GDP per capita	GDP	GDP divided by population by the end of year	$ per capita (2010 prices)
Share of Industry sector	SIG	The ratio of Industry sector value added in GDP	Percent
Share of Service sector	SSG	The ratio of Service sector value added in GDP	Percent
Urban population	UP	The percentage of the urban population in the total population	Percent
Urban population growth	UPG	Population density at the end of year	Persons/Skm

Source: Authors' own design

Note: Kwh= Per hour Kilo watt; Skm=Square Kilometer; $= US dollar

4. Results and Discussion

4.1 Descriptive statistics

The descriptive statistics have revealed that there are significant variations in the correlation between the urbanization variables and energy consumption across the countries during the 1975–2014 period. Table 2 shows the variability in the per capita electric power usage and four commonly used urbanization factors in different countries by using simple tools. Frist, the mean for the per capita electric power consumption in India was much higher compared to other countries. However, increased economic activities is the main cause of the upward trend of per capita electric power consumption, as both the industrial and the services sectors are significantly correlated in the process of urbanization. From Table 2, according to average per capita GDP, Sri Lanka is the 1st position and India is in the second position followed by Pakistan, Bangladesh and Nepal. It is evident that country-wise similar pattern is true for the mean of sectoral share of industry in the GDP and of the share of service sectors in GDP. However, the growth rate of urban population in Bangladesh was 5.30% whereas in Nepal, Pakistan, India and Sri Lanka the growth rate of urban population were 5.22%, 4.30%, 2.97% and 1.11% respectively.

Table 2: Descriptive Statistics of the Variables for 1975-2014

Variables	Statistical tools	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Per capita electric power consumption	Mean	105.69	358.64	52.14	189.90	245.39
	Standard deviation	23.34	53.41	11.41	34.15	35.90
	Coefficient of variation	0.23	0.15	0.24	0.20	0.16
Per capita GDP	Mean	516.99	781.11	418.92	623.03	1656.30
	Standard deviation	47.90	92.15	33.92	71.24	216.26
	Coefficient of variation	0.08	0.10	0.073	0.10	0.12
Sectoral share of industry in GDP	Mean	21.49	27.49	15.44	22.35	27.73
	Standard deviation	1.55	0.90	1.74	1.28	0.94
	Coefficient of variation	0.08	0.03	0.12	0.07	0.03
Sectoral share of services in GDP	Mean	46.81	39.86	35.28	43.78	50.21
	Standard deviation	2.70	1.33	2.54	1.72	2.04
	Coefficient of variation	0.07	0.04	0.08	0.05	0.04
Urban population (% of total population)	Mean	21.79	26.66	11.10	22.42	18.41
	Standard deviation	1.91	0.87	1.05	1.53	0.09
	Coefficient of variation	0.1	0.03	0.11	0.08	0.05
Urban population growth rate (%)	Mean	5.30	2.97	5.22	4.30	1.11
	Standard deviation	0.93	0.18	0.73	0.51	0.26
	Coefficient of variation	0.14	0.06	0.16	0.10	0.25

Source: Authors' calculation from WDI data

As a result, among all countries urban population also increased as a percentage of total population. Urban population growth differs across countries due to the fact that the urban areas, urban population densities and other socioeconomic characteristics of urban households in all SAARC countries are not similar. Because educated people realize to control family size as a way of enhancing their income and economic condition of their households. The mean value for all factors has risen over the four periods. Though absolute variability has increased for some factors and has decreased for others, this trend is also true for the relative measures of variability.

4.2 Impact of urbanization factors on energy consumption

Three methods are employed to examine which urbanization factors are influencing the energy consumption at the country level. First, the ADF unit root test is used for checking the stationarity of all variables. Second, the Johansen cointegration (Johansen, 1988) test is used to examine the cointegration among these variables. Then, the OLS method is employed to estimate the coefficients of the variables.

4.2.1 Unit root test results

For the unit root test, two cases have been considered in this study. In case one both constant and trend terms are included (at the level form) and in case two, only the constant term (at the level form and first difference) is included in the equation. We have chosen this option because macroeconomic variables tend to exhibit a trend over time. As a result, it is more appropriate to consider the regression equation with constant and trend terms at level form. Since first differencing is likely to remove any deterministic trend in the variables, regression should include only the constant term. The results of the ADF unit root test for the country level are shown in Table 3. The unit root test results support that most of all variables for all countries are integrated of order one in case 2, but the results are different in case 1. The results indicate that the majority of the time series for the five different countries are non-stationary, when the variables are defined at the first differences with constant term. While in the case of SIG and SSG for Bangladesh, GDP for India, GDP and SIG for Nepal, SIG for Pakistan, and UPG for Sri Lanka, the null hypothesis of unit root defined at levels can be rejected at 5 % level of significance indicating the stationary time series, i.e., I (0), the EC for all five countries becomes stationary when the series are differenced once; the null hypothesis of unit root can be rejected after first differencing at 5% level of significance. This indicates that the variables are integrated of order 1, i.e., I (1). It indicates that most of all variables at the country level are found as non-stationary at level but stationary at the first difference from Table 3. The I (1) variables may have utility in further econometric analysis, if these variables are cointegrated with each other.

Table 3: Results of ADF Unit Root Test for the Countries

Variables	Bangladesh	India	Nepal	Pakistan	Sri Lanka
Case 1a: Model with constant and trend terms [level form]					
LNEC	0.055	-0.141	3.865	-0.332	2.493
LNGDP	1.316	-1.723	-1.254	-2.012	-0.300
LNSIG	-5.14	-2.714	-1.565	-3.467	-2.672
LNSSG	-4.437	-2.582	-1.676	-2.747	-2.549
LNUP	-4.624	-3.071	-0.795	-2.569	-5.214
LNUPG	-2.224	-2.161	-1.083	-3.679	-5.309
Case 1 b: Model with only constant term [level form]					
LNEU	-4.014	-4.104	-2.960	-2.757	-0.821
LNGDP	5.965	2.912**	2.189**	-1.886	2.703
LNSIG	-4.114**	-2.165	-3.119**	-3.518**	-2.498
LNSSG	-3.899**	0.228	-3.268	-0.614	-0.980
LNUP	-0.731	0.885	-1.701	-2.274	-1.927
LNUPG	-2.205	-1.338	0.824	-0.318	-3.212**
Case 2: Model with only constant term [first difference]					
ΔLNEC	-6.813*	-5.157*	-7.212*	-4.757*	-6.308*
ΔLNGDP	-3.815**	5.902*	-6.673*	-4.412**	-4.509*
ΔLNSIG	-6.623*	-2.497**	-4.860*	-7.963*	-6.460*
ΔLNSSG	-6.936*	-6.077*	-7.629*	-5.589*	-7.273*
ΔLNUP	-3.049**	-2.567	-1.033	-2.365	-2.917**
ΔLNUPG	-4.391**	-4.357**	-4.556*	-3.385**	-7.015*
Note: * and ** indicate statistical significance at 1% and 5% level of significance, respectively.					

4.2.2 Johansen cointegration test results

In the next step, we take EC as the dependent variable, and GDP, SIG, SSG, UP and UPG together as the independent variables, and then the Johansen cointegration among them is tested. Table 4 shows the Johansen cointegration relationship between the variables. The results of Table 4 indicate that, in the case of Bangladesh, starting with the null hypothesis of no cointegration (r =0) among the variables, the trace statistic is 226.90 and exceeds the 95% critical value of the λ_{trace} statistic (critical value is 95.75).

Table 4: Results of the Johansen Cointegration Test

H_0	H_1	Test statistics	5% Critical values	H_0	H_1	Test statistics	5% Critical values
			Bangladesh				
		λ_{trace}				λ_{max}	
r=0	r>0	226.90*	95.75	r=0	r>0	91.71*	40.07
r≤1	r>1	135.18*	69.818	r≤1	r>1	59.45*	33.87
r≤2	r>2	75.738*	47.85	r≤2	r>2	48.00*	27.58
r≤3	r>3	27.73	29.79	r≤3	r>3	16.69	21.13
r≤4	r>4	11.04	15.49	r≤4	r>4	11.02	14.26
r≤5	r>5	0.016	3.84	r≤5	r>5	0.016	3.84
			India				
		λ_{trace}				λ_{max}	
r=0	r>0	171.19*	95.75	r=0	r>0	67.37*	40.07
r≤1	r>1	103.82*	69.81	r≤1	r>1	37.73*	33.87
r≤2	r>2	66.08*	47.85	r≤2	r>2	25.70	27.58
r≤3	r>3	40.38*	29.79	r≤3	r>3	20.80	21.13
r≤4	r>4	19.57*	15.49	r≤4	r>4	14.75*	14.26
r≤5	r>5	4.82*	3.84	r≤5	r>5	4.82*	3.84
			Nepal				
		λ_{trace}				λ_{max}	
r=0	r>0	118.38*	95.75	r=0	r>0	42.67	40.07
r≤1	r>1	75.70*	69.81	r≤1	r>1	26.61	33.87
r≤2	r>2	49.09*	47.85	r≤2	r>2	23.21	27.58
r≤3	r>3	25.87	29.79	r≤3	r>3	18.17	21.13
r≤4	r>4	7.69	15.49	r≤4	r>4	6.85	14.26
r≤5	r>5	0.83	3.84	r≤5	r>5	0.83	3.84
			Pakistan				
		λ_{trace}				λ_{max}	
r=0	r>0	131.94*	95.75	r=0	r>0	64.11*	40.07
r≤1	r>1	67.82	69.81	r≤1	r>1	28.5	33.87
r≤2	r>2	39.25	47.85	r≤2	r>2	19.84	27.58
r≤3	r>3	19.41	29.79	r≤3	r>3	11.45	21.13
r≤4	r>4	7.95	15.49	r≤4	r>4	5.81	14.26
r≤5	r>5	2.13	3.84	r≤5	r>5	2.13	3.84
			Sri Lanka				
		λ_{trace}				λ_{max}	

r=0	r>0	130.66*	95.75	r=0	r>0	40.89*	40.07
r≤1	r>1	89.76*	69.81	r≤1	r>1	35.00*	33.87
r≤2	r>2	54.76*	47.85	r≤2	r>2	25.22	27.58
r≤3	r>3	29.53*	29.79	r≤3	r>3	15.59	21.13
r≤4	r>4	13.94	15.49	r≤4	r>4	13.82	14.26
r≤5	r>5	0.11	3.84	r≤5	r>5	0.11	3.84

Hence it allows us to reject the null hypothesis (r= 0) of no cointegration vector, in favor of the general alternative r ≥1 concluding that at least one cointegration relationship exists among energy consumption from gross domestic product (GDP), the industrial share in GDP, the service share in GDP, urban population and urban population growth. While the null hypothesis of r ≤1,…….., r ≤ 5 cannot be rejected at 5 percent level of confidence. On the other hand, λ_{max} statistic rejects the null hypothesis of no cointegration vector (r =0) against the alternative (r= 1) as the calculated value λ_{max} (0, 1) = 91.71. This exceeds the 95% critical value (40.07). Thus, on the basis of λ_{max} statistic it is found that one long run cointegration exists among energy consumption from gross domestic product, the industrial share of GDP, the service sector sectors share of GDP, urban population and urban population growth. In the case of the remaining SAARC countries (India, Nepal, Pakistan and Sri Lanka), the results are similar to those obtained in the case of Bangladesh. The λ_{trace} and λ_{max} statistics predict the presence of one cointegrating relationship among these in the selected SAARC countries.

4.2.3 Regression results

The results of the linear regression model are presented in Table 5. Generally, the results are logical because the explanatory power of R^2 and adj. R^2 are fairly high for all the five countries, there is no serious autocorrelation problem as shown by Durban Watson Statistics and F-statistics which further reveal that all regressors jointly influence the response variables during the period under the study. Overall the results are logical and extensively satisfactory. The R^2 values are 0.98, 0.99, 0.98, 0.97 and 0.99. They indicate that almost 98%, 99%, 98%, 97% and 99% of the variation in energy consumption is due to GDP, the industrial share in GDP, the service sectors share in GDP, urban population and urban population growth rate in the case of Bangladesh, India, Nepal, Pakistan and Sri Lanka, respectively, while the remaining 1%

variation in energy consumption is due to the other variables which are not included in the model.

Table 5: Results of OLS Method at the Countries

	Bangladesh		India		Nepal	
Variables	**Coeff**	**t-stat**	**Coeff**	**t-stat**	**Coeff**	**t-stat**
Constant	-5.24*	-3.78	-3.08**	-2.27	-2.23	-1.06
LNGDP	1.39*	5.67	0.26**	2.13	0.22***	0.61
LNSIG	1.26*	3.19	0.10	0.41	0.82*	4.50
LNSSG	-0.15***	-0.39	0.08	0.32	-0.34**	1.40
LNUP	1.94*	4.28	2.32*	3.60	0.85**	2.56
LNUPG	0.37	2.65	1.11	6.25	0.56	3.95
R^2	0.985		0.993		0.988	
Adjusted R^2	0.983		0.992		0.987	
D-W stat	1.59		1.54		1.91	
F-stat	463.29		1125.73		592.91	
	Pakistan				**Sri Lanka**	
Variables	**Coeff**	**t-stat**			**Coeff**	**t-stat**
Constant	-14.81*	-4.35			-19.38*	-5.00
LNGDP	1.92*	5.70			1.04*	19.51
LNSIG	0.82*	3.26			0.16	-0.85
LNSSG	-0.097	-0.16			-1.61*	8.92
LNUP	1.40	1.30			3.87*	3.17
LNUPG	0.57	1.81			0.02	1.57
R^2	0.979				0.994	
Adjusted R^2	0.978				0.993	
D-W stat	1.25				1.42	
F-stat	328.22				1254.61	

Note: *, ** and *** indicate statistical significance at 1%, 5% and 10% level of significance, respectively.

The Durban Watson values in all the models are close to two (2) and indicate that the value is lying in no autocorrelation zone. The F statistics values are reasonably high, indicating that all the independent variables have a joint significance effect on the response variable that is urbanization factors influencing energy consumption in the study. It is evident from Table 5, that the estimates of linear regression indicate that energy consumption is positively related to the GDP and negatively related to the service sector share in GDP in all the five countries. The coefficient of GDP is statistically significant at 1% level of significance for Bangladesh, Pakistan and Sri Lanka, while at 5% and 10% levels for India and Nepal, respectively. The coefficient of the industrial sector share in GDP is statistically significant at 1% level of significance for Bangladesh, Nepal and Pakistan. The result shows that a 1% increase in the industrial sector's share in GDP leads to an increase in energy consumption of 1.26% and .82%, respectively, in Bangladesh, and in both Nepal and Pakistan. The result further indicates that a 1% increase in the service sector's share in GDP leads to a reduction in energy consumption of 0.15%, 0.34% and 1.61%, respectively, in Bangladesh, Nepal and Sri Lanka. The result for urban population indicates that a 1% increase in urban population leads to an increase in energy consumption by 1.94%, 2.32%, 0.85% and 3.87%, respectively, for Bangladesh. India, Nepal and Sri Lanka.

5. Conclusion

The objective of this study was to evaluate the effects of urbanization factors on the energy usage and the variability of results for the five different selected countries by using the OLS method with time series data. The results have revealed that the impacts of urbanization variables vary among the five countries. The overall findings confirm that urbanization variables (GDP, industrial sector share in the GDP, services sector share in the GDP, urban population) have had significant effects on energy consumption by using the linear regression method, although the effects vary among the countries. The findings indicate that energy usage is positively related to a country's GDP (gross domestic product) and is negatively related to the service sector share in the GDP in all five countries. The industrial sector share in the GDP is statistically significant for Bangladesh, Nepal, and Pakistan. Moreover, the urban population share is statistically significant for most countries' energy consumption. Overall, it is found that there are causal relationships between urbanization factors and energy usage in the SAARC region from this study. Based on these findings, the following specific recommendations are made for reducing energy usage or for efficiently using the energy in the SAARC region countries challenged by rapid urbanization. Most of the SAARC countries are developing economies where energy usage is higher due to the higher growth rate of these economies. These countries' governments should take the initiative to invest in energy efficient technologies to lead the country toward an economic growth for sustainable development. In addition, SAARC countries are, developing economies which export different types of manufactured products to developed countries, due to the availability of these products at a much cheaper rate. This is another reason for the increase in the industrial sector's share in GDP, as well as the increase in energy usage. The governments of these countries should change their industrial policies by providing incentives to these industries to adopt new technologies such as green technology and energy efficiency, which could reduce their energy usage. However, infrastructure and transportation are two significant subsectors of the service sector's share in the GDP (Ali, Bakhsh and Yasin, 2019; Bilgili, Koçak, Bulut and Kuloglu, 2017). These two components of the urbanization process are increasing the demand for energy in urban areas. So, sustainable urbanization policies are important to secure efficient energy use or to reduce energy usage. The governments and policymakers of these countries should develop policies supporting investments to develop an energy-efficient public transportation system and discourage private transportation and energy intensity in the infrastructure with the aim to reduce energy usage in urban areas. The time series data used in the study, that found in the World Development Indicators database, but data of all countries of the SAARC region are not available from this source or from other sources. As a result, this study cannot present an overall scenario of this region. So, the lack of availability of data from all SAARC countries is a limitation of the study.

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References

Abbasi, M. A., Parveen, S., Khan, S. and Kamal, M. A. (2020). Urbanization and energy consumption effects on carbon dioxide emissions: Evidence from Asian-8 countries using panel data analysis. *Environmental Science and Pollution Research, 27*, 18029-18043. https://doi.org/10.1007/s11356-020-08262-w

Afridi, M. A., Kehelwalatenna, S., Naseem, I. and Tahir, M. (2019). Per capita income, trade openness, urbanization, energy consumption, and CO2 emissions: an empirical study on the SAARC Region. *Environmental Science and Pollution Research, 26*, 29978–29990. https://doi.org/10.1007/s11356-019-06154-2

Ahmad, W. and Majeed, M. T. (2019). The impact of renewable energy on carbon dioxide emissions: an empirical analysis of selected South Asian countries. *Ukrainian Journal of Ecology, 9*(4), 527-534.

Ali, R., Bakhsh, K. and Yasin, M. A. (2019). Impact of urbanization on CO2 emissions in emerging economy: Evidence from Pakistan. *Sustainable Cities and Society, 48,*(101553). https://doi.org/10.1016/j.scs.2019.101553

Arouri, M., Youssef, A. B., Nguyen-Viet, C. and Soucat, A. (2014). Effects of urbanization on economic growth and human capital formation in Africa. *PGDA Working Paper No. 119*.

Bakirtas, T. and Akpolat, A. G. (2018). The relationship between energy consumption, urbanization, and economic growth in new emerging-market countries. *Energy, 147,* 110-121.

Behera, S. R. and Dash, D. P. (2017). The effect of urbanization, energy consumption, and foreign direct investment on the carbon dioxide emission in the SSEA (South and Southeast Asian) region. *Renewable and Sustainable Energy Reviews, 70,* 96–106.

Bilgili, F., Koçak, E., Bulut, Ü. and Kuloglu, A. (2017). The impact of urbanization on energy intensity: Panel data evidence considering cross-sectional dependence and heterogeneity. *Energy, 133*, 242-256.

Chary, S. R. and Bohara, A. K. (2010). Carbon emissions, energy consumption and income in SAARC countries. *South Asia Economic Journal, 11*(1), 21-30. doi: 10.1177/139156141001100102

Cetin, M., Ecevit, E. and Yucel, A. G. (2018). Structural breaks, urbanization and CO_2 emissions: Evidence from Turkey. *Journal of Applied Economics and Business Research, 8*(2), 122-139. ISSN 1927-033X

Chikaraishi, M., Fujiwara, A., Kaneko, S., Poumanyvong, P., Komatsu, S. and Kalugin, A. (2015). The moderating effects of urbanization on carbon dioxide emissions: A latent class modeling approach. *Technological Forecasting and Social Change, 90,* 302–317.

Dickey, D. A. and Fuller, W. A. (1979). Distribution of the estimators for autoregressive time series with a unit root. *Journal of the American Statistical Association, 74*(366a), 427-431. DOI: 10.1080/01621459.1979.10482531

Ewing, R. and Rong, F. (2008). The impact of urban form on U.S. residential energy use. *Housing Policy Debate, 19* (1), 1–30.

Gasimli, O., Haq, I., Gamage, S. K. N., Shihadeh, F., Rajapakshe, P. S. K. and Shafiq, M. (2019). Energy, trade, urbanization and environmental degradation nexus in Sri Lanka: Bounds testing approach. *Energies, 12*(9), 1-16. DOI:10.3390/en12091655

Gujrati, D. (2004). *Basic econometrics* (4th ed.). McGraw-Hill, New York, USA.

Hocaoglu, F. O and Karanfil, F. (2013). A time series-based approach for renewable energy modeling. *Renewable and Sustainable Energy Reviews, 28*, 204–214.

International Energy Agency (IEA) (2012). World Energy Outlook, Paris, France. https://www.iea.org/publications/freepublications/publication/English.pdf

International Energy Agency (IEA). (2015). *World energy outlook special report on Southeast Asia*. Paris, France. Retrieved from: https://www.iea.org/newsroom/news/2015/october/emergence-of-southeast-asia-as-energy-giant-carries-risks-opportunities.html

Johansen, S. (1988). Statistical analysis of co-integration vectors. *Journal of Economic Dynamics and Control, 12*(1-2), 231–254.

Johansen, S. and Juselius, K. (1990). Maximum likelihood estimation and inference on co-integration with applications to the demand for money. *Oxford Bulletin of Economics and Statistics, 52*(2), 169–210.

Jones. D. W. (1991). How urbanization affects energy use in developing countries. *Energy Policy, 19*(7), 621-630.

Lariviere I. and Lafrance, G. (1999). Modeling the electricity consumption of cities: Effect of urban density. *Energy Economics, 21*(1), 53–66.

Lin, B. and Ouyang, X. (2014). Energy demand in China: Comparison of characteristics between the US and China in rapid urbanization stage. *Energy Conversion and Management, 79*, 128–139.

Mrabet, Z., Alsamara, M., Saleh, A. S. and Anwar, S. (2019). Urbanization and non-renewable energy demand: A comparison of developed and emerging countries. *Energy, 170*, 832-839.

Mudakkar, S. R., Zamanb, K., Shakirb, H., Arifc, M., Naseemb, I. and Nazd, L. (2013). Determinants of energy consumption function in SAARC countries: Balancing the odds. *Renewable and Sustainable Energy Reviews, 28*, 566-574.

Mulali, U. A., Ozturk, I. and Lean, H. H. (2015). The influence of economic growth, urbanization, trade openness, financial development, and renewable energy on pollution in Europe. *Natural Hazards, 79*, 621-644. DOI 10.1007/s11069-015-1865-9

Munir, S. and Khan, A. (2014). Impact of fossil fuel energy consumption on CO_2 emissions: Evidence from Pakistan (1980-2010). *The Pakistan Development Review, 53*(4), 327-346.

Ozturk, I. and Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics, 36*, 262–267.

Parikh J. and Shukla V. (1995). Urbanization, energy use and greenhouse effects in economic development. *Global Environmental Chang*e, *5*(2), 87–103.

Poumanyvong, P. and Kaneko, S. (2010). Does urbanization lead to less energy use and lower CO2 emissions? A cross-country analysis. *Ecological Economics, 70,* 434–444.

Rahman, S. (2019). The nexus between economic growth, urbanization and health industry in Bangladesh- An empirical approach. *International Journal of Business Management and Economic Review, 2*(1), 105-123. ISSN: 2581-4664

Sadorsky, P. (2013). Do urbanization and industrialization affect energy intensity in developing countries? *Energy Economics, 37,* 52-59.

Salim, R. A. and Shafiei, S. (2014). Urbanization and renewable and non-renewable energy consumption in OECD countries: An empirical analysis. *Economic Modelling, 38,* 581–591.

Shahbaz, M., Hye, Q. M. A., Tiwari, A. K. and Leitão, N. C. (2013). Economic growth, energy consumption, financial development, international trade and CO2 emissions in Indonesia. *Renewable and Sustainable Energy Reviews, 25*, 109–121.

Shahbaz, M., Loganathan, N., Sbia, R. and Afza, T. (2015). The effect of urbanization, affluence and trade openness on energy consumption: A time series analysis in Malaysia. *Renewable and Sustainable Energy Reviews, 47*, 683–693.

South Asian Association for Regional Cooperation (SAARC). (2007). *Fourteenth summits of the South Asian Association for Regional Cooperation*. New Delhi, India. Retrieved from: https://en.wikipedia.org/wiki/List_of_SAARC_summits#Fourteenth_summit_14th_India

South Asian Association for Regional Cooperation (SAARC). (2015). *Report for selected countries and subjects*. International Monetary Fund, Washington DC, USA. Retrieved from: https://www.imf.org/external/pubs/ft/weo/2015/01/weodata/weorept.aspx

Sustainable Energy for All. (2013). *Renewable Energy*, http://www.se4all.org/wp-content/uploads/2013/09/9gtf_pdf, doi: 10.1596/978-1-4648-0200-3

United Nations (UN). (2015). *Transforming our world: The 2030 agenda for sustainable development.* United Nations, New York, USA. Retrieved from: https://sustainabledevelopment.un.org/post2015/transformingourworld/publication

United Nations (UN). (2019). *World urbanization prospects the 2018 revision*. Population Division, Department of Economic and Social Affairs, United Nations, New York, USA. Retrieved from: https://population.un.org/wup/Publications/Files/WUP2018-Report.pdf

Wang, S., Zeng, J., Huang, Y., Shi, C. and Zhan, P. (2018). The effects of urbanization on CO2 emissions in the Pearl River Delta: A comprehensive assessment and panel data analysis. *Applied Energy*, *228*, 1693-1706.

Wang, Y., Kang, Y., Wang, J. and Xu, L. (2017). Panel estimation for the impacts of population-related factors on CO2 emissions: A regional analysis in China. *Ecological Indicators*, *78*, 322-330.

Wang, Y., Li, L., Kubota, J., Han, R., Zhu, X. and Lu, G. (2016). Does urbanization lead to more carbon emission? Evidence from a panel of BRICS countries. *Applied Energy*, *168*(C), 375-380. DOI: 10.1016/j.apenergy.2016.01.105

World Development Indicators (WDI) (2012). http://documents.worldbank.org/curated/en/553131468163740875/World-development-indicators-2012

World Development Indicators (WDI) (2016). https://openknowledge.worldbank.org/handle/10986/23969?show=full

Wu, H., Haob, Y. and Weng, J. (2019). How does energy consumption affect China's urbanization? New evidence from dynamic threshold panel models. *Energy Policy*, *127*, 24-48.

Yassin, J. and Aralas, S. B. (2019). The urbanization effect on $CO2$ emissions: New evidence of dynamic panel heterogeneity in Asian countries. *International Journal of Economics and Management*, *1*(1), 8 – 18.

Zaharia, A., Diaconeasa, M. C., Brad, L., Lădaru, G. R. and Ioanăș, C. (2019). Factors Influencing Energy Consumption in the Context of Sustainable Development. *Sustainability*, *11*(15), 41-47. https://doi.org/10.3390/su11154147

Zeb, R., Salar, L., Awan, U., Zaman, K. and Shahbaz, M. (2014). Causal links between renewable energy, environmental degradation and economic growth in selected SAARC countries: Progress towards green economy. *Renewable Energy, 71,* 123-132. http://dx.doi.org/10.1016/j.renene.2014.05.012

Zhang M. and Zhao P. (2016). The impact of mixed land-use on residents' travel energy consumption: new evidence from Beijing. In: Proceedings of 14th World Conference on Transport Research. Shanghai, China.

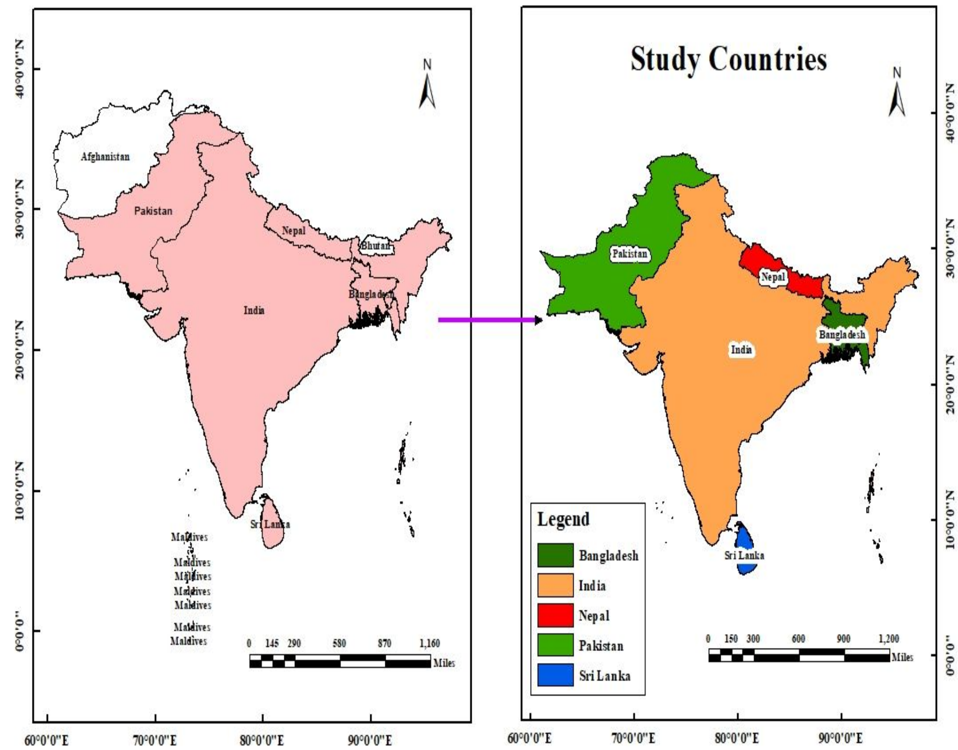
Zhang, C. and Lin, Y. (2012). Panel estimation for urbanization, energy consumption and CO2 emissions: A regional analysis in China. *Energy Policy, 49*, 488-498.

Zhao, P and Zhang, M. (2018). The impact of urbanization on energy consumption: A 30-year review in China. *Urban Climate, 40*, 940-953.

Zhu, Q. and Peng, X. (2012). The impacts of population change on carbon emissions in China during 1978–2008. *Environmental Impact Assessment Review, 36*, 1–8.

Appendix A

SAARC Region



Source: DIVA GIS