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RESEARCH ARTICLE

Impact of urbanization on energy intensity in SAARC countries: an empirical analysis

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Abstract: This study aims to examine the effect of urbanization on energy intensity in SAARC countries and compare Sri Lanka's status with other SAARC countries between 1990 and 2015. This study used the urban population as a proxy variable for urbanization. Other control variables in the model are per capita income and squared value of per capita income (PCI), capital formation, industrialization, labour and carbon dioxide emissions, squared value of carbon dioxide emissions and six country dummy variables to detect country effect. Fixed effects model and Least Squared Dummy Variable model (LSDV) with country-urbanization interactive variables model were employed in the estimation. Our results indicate urbanization in the SAARC region increases energy intensity in all countries except Sri Lanka. With urbanization, Pakistan has the fastest increase in energy intensity. Our results confirm Environmental Kuznets Curve (EKC) hypothesis which is consistent with the literature. Industrialization and labour force participation lower energy intensity. Carbon dioxide emission and the squared value of that variable show a U-shaped behaviour with energy intensity. This implies higher energy use further increases energy intensity and needs mitigating policies to curb higher energy use. According to the results, Pakistan has the lowest energy intensity and Sri Lanka has higher energy intensity among SAARC countries. Sri Lanka needs to lower the energy intensity by reducing inefficient energy use in all possible sectors such as transportation. Since urbanization significantly reduces energy intensity in Sri Lanka, efficient public transportation coupled with planned urbanization will help to lower our energy intensity in the long run.

Keywords*:* Capital formation, energy intensity, fixed effect, per capita income, urbanization.

INTRODUCTION

Urbanization is one of the major causes of energy consumption in South Asia. The region's urban population is expected to grow from 400 million in 2015 to 700 million by 2050. This growth exerts a lot of pressure on the region's energy resources and leads to increased energy consumption, which results in higher levels of greenhouse gas emissions. In many countries, economic prosperity is coupled with urbanization and industrialization, which drives up the energy demand. Yet, countries face a trade-off between economic development and emissions due to higher energy consumption. Energy intensity measures the amount of energy required to produce a unit of economic output. A standard measurement that is widely used to compare the amount of utilized energy at the aggregate level, relative to the country's output (GDP) is energy intensity. When discussing energy intensity, it usually refers to all forms of energy consumed in an economy. This includes electricity, fossil fuels (such as coal, oil and natural gas), renewable energy sources and any other forms of energy used in production, transportation and other sectors of

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the economy. It can be interpreted as a proxy for the effectiveness of the amount of energy used in a country. The equation for energy intensity is as follows;

$$Energy\ intensity = \frac{Total\ Energy\ Consumption\ (MJ)}{Economic\ output\ (USD)}$$

Here, Energy Consumption refers to the total amount of energy used by a country. It encompasses all forms of energy, including electricity, natural gas, oil, coal and renewable sources and economic output measured by the Gross Domestic Product (GDP) of a country that represents the total value of all goods and services produced over a specific period (Zheng & Walsh, 2019). Energy consumption is typically measured in units such as joules (J), kilowatt-hours (kWh), British Thermal Units (BTU), or tons of oil equivalent (toe), while Gross Domestic Product (GDP) is measured in US dollars (USD). To calculate energy intensity, energy consumption is first quantified in a standard unit such as megajoules (MJ). By dividing the total energy consumption in megajoules by the GDP in US dollars, energy intensity is expressed in MJ per USD. MJ per USD as a measurement of energy intensity was used by Xiongfeng Pana *et al.*, (2019), Huang & Chen (2020) and Elliott, Sun & Zhu (2017). This conversion allows for a clear comparison of how much energy is consumed for every dollar of economic output.

A lower energy intensity means that less energy is required to generate economic output, which often implies a sustainable and more efficient economy. Conversely, a higher energy intensity suggests that more energy is needed for the same economic production, which shows inefficient energy-intensive processes.

A country should always target its energy policy to achieve a lower energy intensity. The good news is, in the SAARC countries, it has been recorded that there was a 1.5% decline in the energy intensity from 1990 to 2010. This is a remarkable achievement in the middle of growing energy demand in the region. This study empirically examines the links between energy intensity and urbanization in order to get some insights into how urbanization process places countries in different positions in emission and climate prospects.

Urbanization has been identified as one of the crucial factors that affects energy intensity, even though it has shown mixed effects in different countries. Urbanization changes the lifestyles of the people, i.e., domestic energy usage for different applications, such as cooking, lighting, heating & cooling and transportation. In an effort to cope with urban living, urban dwellers have to make changes within their budget in response to urban energy prices. On the other hand, urban planners make efforts to plan future green cities with some novel concepts such as smart cities, which could expect to depend on less energy.

The papers that examine the effect of urbanization on energy intensity reflect somewhat mixed results in different countries. This could be due to differences in energy efficiency achievements and economic structure. For example Koyuncu, Beşer & Alola, (2021), Elliott, Sun & Zhu, (2017) and Rafiq, Salim & Nielsen, (2016) found a positive impact of urbanization on energy intensity in Turkey and China. At the same time, research done by Bilgili *et al.*, (2017) shows a negative impact in ten Asian countries, namely Vietnam, Bangladesh, Malaysia, Nepal, Thailand, China, South Korea, Indonesia, India and the Philippines. Liu & Xie (2013) in China and Sadorsky (2013) found that there is a mixed impact of urbanization on energy intensity in 76 developing countries.

Urbanization is the process by which an increasing amount of a country's population is concentrated in urban areas, such as towns and cities, rather than rural areas. It includes the migration of people from rural to urban areas due to improved living conditions, economic opportunities and access to various amenities and services. Urbanization is accompanied by the growth and expansion of cities, the development of industries and infrastructure and changes in cultural and social dynamics (UN Department of Economic and Social Affairs, 2018).

As shown earlier, many studies use urban population as a proxy for the urbanization. In Sri Lanka, urban areas are defined to comprise municipal and urban council areas. In India, urban areas are defined as towns, which include places with a municipal corporation, municipal area committee, town committee, notified area committee, or cantonment board. Additionally, any place with 5,000 or more inhabitants, a density of not less than 1,000 persons per square mile or 400 per square kilometre, pronounced urban characteristics and at least three-fourths of the adult male population employed in pursuits other than agriculture is considered urban. In Pakistan and Bangladesh, urban areas are referred to as places with a municipal corporation, town committee, or cantonment (Weeraratne, 2016). The highest share of the urban population is recorded in Bhutan as at 43 percent, Sri Lanka shows the lowest share of urban population as at 18.9 percent. Maldives, Pakistan and India had 41.1 percent, 37.4 percent and 35.4 percent urban population, respectively, in 2021. Figure 1 shows an increasing trend in urban population share in the SAARC region in all countries except Sri Lanka where it shows a minimal decline in value over time.

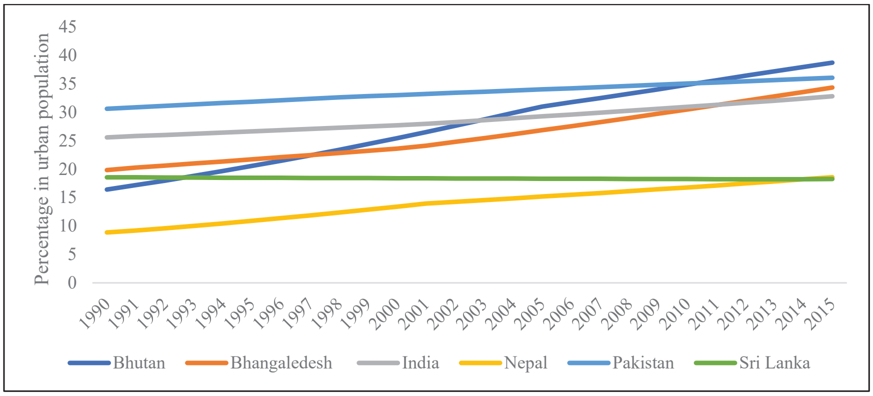

Figure 1: Trend of urbanization in SAARC countries (1990-2015)

Source: World Bank data,1990-2015

The relationship between urbanization and energy intensity has not been investigated in the literature for the SAARC countries and this paper focuses on this issue. Many studies do not identify the differential effects of urbanization on energy use. Analysis in this study is helpful to introduce integral policy measures in both urban and energy use planning to identify the level of effort that each country must put into the SAARC region. Such efforts will help to achieve sustainable economic prosperity in the long run by mitigating adverse consequences of higher energy intensity. Therefore, this examines new insights into urbanization and energy use in the SAARC region.

To understand the pattern of energy intensity, it is crucial to first understand the trends in energy consumption. Therefore, the Figure 2.a and Figure 2.b illustrate the pattern of primary energy consumption. It is important to note that primary energy sources such as coal, oil, natural gas, nuclear energy and renewables before they get converted into secondary forms of energy such as electricity and petroleum products for convenience in transport, delivery and convenience at points of end-use. This focus on primary energy provides an insight into the foundational energy inputs driving economic activity and helps in analysing the broader energy intensity trends. Figure 2 shows the trend of energy consumption in the SAARC countries from 1990 to 2015. (This study derived the energy intensity directly from World Bank data which is directly sourced from https://databank.worldbank.org/source/sustainable-energy-for-all/Series/6.1_PRIMARY.ENERGY.INTENSITY and it was not computed it directly from this primary energy consumption figures.)

According to the Figure 2.a, the highest amount of primary energy consumption is in India. It was 2,300.7 TWh in 1990 and increased to 8,030.2 TWh in 2015 due to the rapid population growth. Except in India, total primary energy consumption in other SAARC countries shows a very small increase.

LITERATURE REVIEW

Energy

Energy is a fundamental concept representing the capacity to perform work or produce change, existing in various forms that can be converted from one type to another. Key forms of energy include kinetic energy, associated with the motion of objects; potential energy, stored due to an object's position or configuration; thermal energy, related to temperature and particle movement; chemical energy, stored in chemical bonds and released during reactions; electrical energy, resulting from the flow of electrons; and nuclear energy, released during nuclear reactions. Energy resources are the natural or synthetic sources from which energy is derived. They are categorized into renewable resources, such as solar energy, wind energy, hydropower, geothermal energy and biomass, which are replenished naturally and sustainably. Non-renewable resources, include fossil fuels (coal, oil, natural gas) and nuclear fuels (uranium, plutonium), which are finite and deplete over time. A clear understanding of these concepts is essential for analysing the energy intensity which is defined as the total energy consumption divided by the GDP of a given country (Bhattacharyya, 2011). This study utilizes country- wide energy intensity data

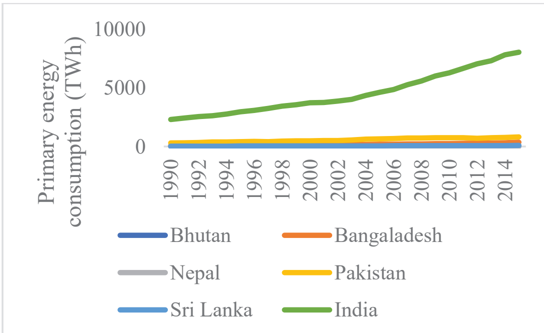

Figure 2.a: Trend of energy consumption in SAARC countries including India (1990-2015)
Source: World Bank data,1990-2015

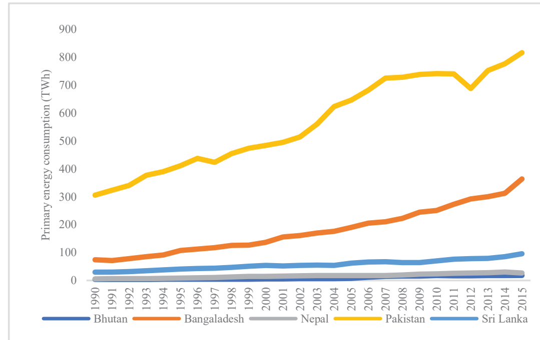

Figure 2.b: Trend of energy consumption in SAARC countries excluding India (1990-2015)
Source: World Bank data,1990-2015

published by the World Bank and the unit of measure is MJ / $ (2011 PPP). (See Appendix I)

Energy intensity and energy efficiency

Reducing energy intensity is linked with advanced energy conversion and energy efficiency methods. Such activities help to increase GDP of a country with a lower energy use (Martínez, Ebenhack & Wagner, 2019).

Energy efficiency refers use of less energy to produce a given level of production. At aggregate level, the amount of energy used to produce one unit of GDP is defined as energy efficiency. Energy efficiency improves when a given level of service is provided with reduced amounts of energy inputs or services are enhanced for a given amount of energy input (U.S. Department of Energy, 2023).

Further, Energy efficiency is the ratio of output of performance, service, goods or energy, to input of energy. Energy efficiency is measured as the amount of energy output for a given energy input. On the contrary, energy intensity calculated as units of energy per unit of GDP, is used to measure the energy inefficiency of a country (Erbach, 2015).

Improvement of energy efficiency is an important factor that contributes to reducing energy intensity. Also, reducing energy intensity is a proxy for improvement of energy efficiency. Lower energy intensity represents an efficient allocation of energy resources to generate wealth and a high quality of life (Martínez, Ebenhack & Wagner, 2019). Further, energy intensity improvement refers the decrease of energy supply per unit of GDP as the indicator to measure the energy efficiency.

Simply we can differentiate the energy intensity and energy efficiency as energy intensity involves the use of energy to produce a given level of output, but energy efficiency involves using technology that requires less amount energy to perform the same function. However, identifying the link between energy intensity and efficiency is more complex and controversial.

Energy intensity by region

Improving energy efficiency of the world to a double rate is one of the target goals of 7th Sustainable Development Goal: affordable and clean energy. To achieve this target, the global energy intensity should be reduced by 3.2 percent per year.

But the annual reduction of energy intensity was 2.6 percent in 2019. It shows that the world has fallen short to achieve SDG 7 as a consequence of failing to reduce the energy intensity. According to the International Energy Agency, reasons for the recent trend of energy intensity are rapid increase in energy-intensive economies and weaker energy efficiency policy in world economies (IEA, 2022).

On the other hand, improvement of energy intensity recorded 3.4 percent in developing Asia in 2020. It was the fastest progress among developing economies. The reason for this improvement was significant energy efficiency policies including Nationally Determined Contributions (NDCs) declared at COP26.

Above graph shows energy intensity improvement of the world in the past 20 years (between 1990 and 2010). According to the graph, the fastest rate of energy

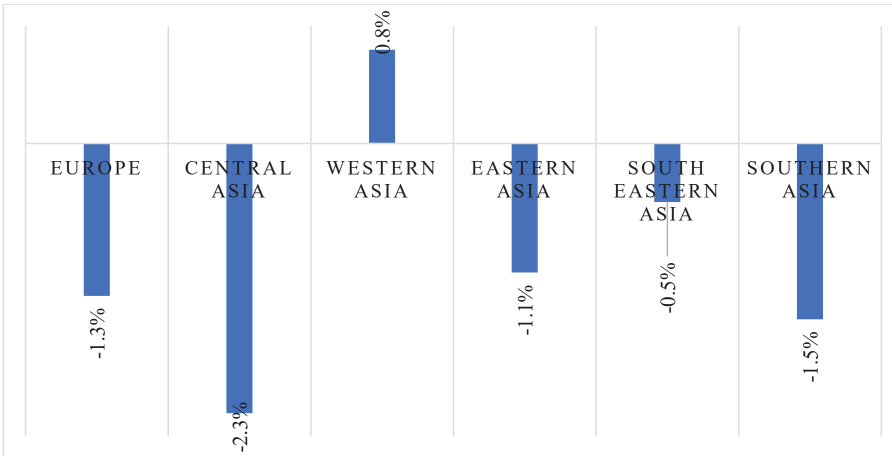

Figure 3: Annual Average Growth rate of Energy intensity between 1990 and 2010
Source: International Energy Agency, 2012

intensity improvement has been recorded in Central Asia as a 2.3 percent reduction between 1990 and 2010. Southern Asia and Europe region rank second and third in terms of improving energy intensity as 1.5 and 1.3 percent respectively. The slowest performing region to improving energy intensity is South Eastern Asia. It was a 0.5 percent improvement in energy intensity over 20 years. On the other hand, Western Asia is the region to show a deterioration in the energy intensity improvement.

Between 2010 and 2018, average improvement of energy intensity in Eastern Asia and South Eastern Asia recorded a rate of 3.1 percent. In Southern Asia and Central Asia, the average annual improvement rate was 2.6 percent. Nonetheless, Western Asia was still at a 0.8 percent increase in energy intensity between 2010 and 2018.

Since 2000, The EU and the USA have shifted towards less energy-intensive industry production and reduced energy intensity by two percent. But in 2020, it was much slower in both regions as recorded at -4.2 percent and -0.6 percent respectively. The high energy intensity recorded in China, Taiwan, South Korea and the Middle East countries is a consequence of the domination of energy-intensive industries. Lower energy prices and commodity-exporting-based economies failed to promote energy efficiency in 2020. In Asia, energy intensity shows an increasing trend, especially in China and India (Enerdata, 2021).

Energy intensity in SAARC countries

South Asian Association for Regional Cooperation is an organization of eight South Asian nations from economic and political perspectives. The member countries are Bangladesh, Bhutan, India, the Maldives, Pakistan, Afghanistan, Nepal and Sri Lanka. South Asia includes three of ten countries with the highest population in the world and their average annual growth was 5.9 percent between 2000 and 2018. In this region, the energy requirement is high to meet the demand of its 23.9 percent (in 2020) population. South Asian region depends on imports of commercial fossil fuels with lower energy efficiency.

Above graph shown that Bhutan recorded a high energy intensity in 2015. After Bhutan, rank in energy intensity from highest to lowest were Nepal, India, Maldives, Pakistan and Sri Lanka. According to the World Bank, Energy intensity registered 3.6 MJ / $ (2011 PPP), 3.3 MJ / $ (2011 PPP) and 2.3 MJ / $ (2011 PPP) in 1990, 2000 and 2010 respectively in Sri Lanka. It is shown that Sri Lanka also recorded slow and unstable energy intensity improvement. Accordingly, it has taken almost 20 years to drop approximately 56 percent in energy intensity from 1990 to 2010 (from 3.6 MJ / $ (2011 PPP) to 2.3 MJ / $ (2011 PPP)) of energy intensity. Energy intensity values in Bhutan in 1990,2000 and 2010 were 30 MJ, 21.7 MJ and 12.5 MJ. It shows that Bhutan recorded a faster improvement in energy intensity over every ten years than other SAARC countries, but it was

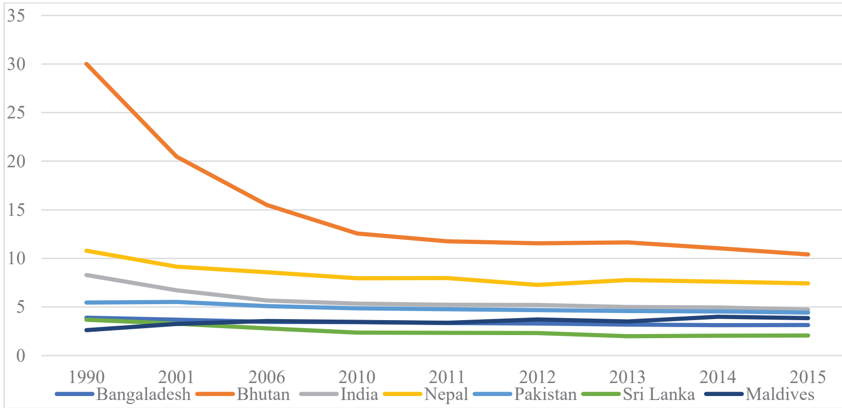

Figure 4: Energy intensity in Sri Lanka and other South Asian countries from 1990-2015
Source: World Bank data (1990-2015)

the highest level among them. Seasonality and weather conditions are the main barriers for reducing the energy intensity in Bhutan. Power generation in Bhutan has no peaking plants or reservoirs but mostly depends on the seasonality of the river. It pushes direct risk to energy efficiency and energy security as a result, as energy intensity is higher than other SAARC countries.

Bhutan is one of the countries to export energy to earn revenue, but it is importing a significant amounts of fossil fuel for generators, transportation and cooking needs. It also causes a worse Balance of trade and energy security than other SAARC countries (Shrestha *et al.*, 2021). Nepal recorded the highest energy intensity next to Bhutan among SAARC countries. It was 10.7 MJ / $ (2011 PPP), 9.2 MJ / $ (2011 PPP) and 7.9 MJ / $ (2011 PPP) in 1990, 2000 and 2010 respectively. Nepal is a country that has a large potential for hydropower. Unfortunately, less than two percent of hydropower is currently used. Moreover, The United Nations warns Nepal that "energy efficiency efforts in the country are still in their infancy". Nepal is identified as the poorest country in energy intensity due to lack of human resources and awareness of clean energy, the absence of an energy efficiency strategy and the agency to institutionalize energy efficiency (Shrestha *et al.*, 2021). Moreover, Nepal's urban population uses solid fuels and it causes 7,500 deaths annually due to low energy efficiency and lack of capable human resources to use modern energy technologies (Ministry of Population and Environment, 2017). Due to those situations, Nepal ranks as the country with the highest energy intensity level next to Bhutan.

India's energy intensity recorded 8.2 MJ / $ (2011 PPP), 6.5 MJ / $ (2011 PPP) and 5.3 MJ / $ (2011 PPP) in 1990, 2000 and 2010 respectively. In India, 44.7 percent rural population and 7.3 percent urban population do not have electricity and they still use firewood. They mostly depend on fuel wood and animal waste for their energy needs, although India is one of the countries with the top potential for using renewable and clean energy technologies like solar and wind, because of their supportive geographical, natural resources and climate conditions. From 1982 India developed a policy based on cost-effective PV technology, including Demonstration and Technology Utilization, Testing and Standardization, Industrial and promotional activities and Research and Development (Shrestha *et al.*, 2021). Those activities help to maintain lower energy intensity in India than Bhutan and Nepal.

In case of Pakistan, their energy intensity values in 1990, 2000 and 2010 were 5.3 MJ / $ (2011 PPP), 5.5 MJ / $ (2011 PPP) and 4.8 MJ / $ (2011 PPP) respectively. In this way, ten percent urban population lives without electrification and they use traditional energy sources like biomass in inefficient stoves. This reliance on biomass releases harmful pollutants, leading to indoor air pollution, which is associated with respiratory and cardiovascular issues, causes more than 50,000 deaths per year (WHO, 2005; Energypedia, 2017). However, successful energy policies help to maintain a less energy intensity level than Bhutan, India and Nepal namely; the Alternative and Renewable Energy Policy in 2011 and Pakistan Net Metering Policy for Solar PV and Wind Projects and power generation policy in 2015.

Bangladesh energy intensity level is lower than the other SAARC countries except Sri Lanka. It recorded 3.8 MJ / $ (2011 PPP), 3.5 MJ / $ (2011 PPP) and 3.4 MJ / $ (2011 PPP) in 1990, 2000 and 2010 respectively. 60-66 percent urban people of Bangladesh still use cow dung, agricultural waste and wood for cooking and only seven percent of urban people use clean cooking fuels and technologies because of their lack of awareness about accessing modern and clean energy technologies (Aziz, Barua & Chowdhury, 2022). Even though successful energy policies lead to a better stage in energy intensity than other SAARC countries namely; Renewable Energy and Energy Efficiency Programme-2006, (Intended) Nationally Determined Contributions to promote off-grid solar energy as well as improved cook stoves, The Private Sector Power Generation Policy, Country Action Plan for Clean Cook stoves (CAP) in November 2013 (http://www.sreda.gov.bd/). In an overall sense, SAARC countries including Sri Lanka slowly reduce energy intensity levels (Asian Development Bank, 2019).

Energy intensity in Sri Lanka

Sri Lanka has the high energy intensity among the countries with per capita GDP between $3,000 and $4,500 in the world (ADB, 2019). Sri Lanka fulfilled its 46 percent of its energy requirement through domestic resources while 54 percent of energy resources and commodities were imported in 2017 (ADB, 2019). Sri Lanka has a greater dependence on imported energy resources and commodities, which annually requires around USD 3.7 Billion (CBSL, 2021). Therefore, reducing energy intensity (defined here as energy consumption per unit of GDP) should be one of the highest priority policies in Sri Lanka and other SAARC countries. Lower energy intensity signifies improved energy efficiency, allowing the economy to produce more output with less energy.

Empirical evidence

Literature about the relationship between energy intensity and urbanization was done by Liu & Xie (2013) in China. This study used a cointegration test to check long-term relationships and Asymmetric Analyses and Vector Error Correction Model were applied to check the deviation of variables with equilibrium. This study found that urbanization shows an asymmetric impact on energy intensity and there was a nonlinear relationship between urbanization and energy intensity in the research area. This study also found that when the threshold was reached, the adjustment process of energy intensity towards equilibrium was high and the growth rate of energy intensity was higher than urbanization.

Sadorsky (2013) also analysed the impact of income, urbanization and industrialization on Energy Intensity in developing countries. This study has chosen 76 developing countries for the panel data analysis. This study found that income has a negative impact on energy intensity that a one percent increase in income leads to reduce energy intensity by 0.45 percent to 0.35 percent and industrialization harms energy intensity that a one percent increase in industrialization corresponded to decrease energy intensity by 0.007 percent to 0.12 percent. At the same time, urbanization shows a mixed impact on energy intensity using heterogeneous panel regression techniques namely common correlated effect estimators and mean group estimators.

However, the study which was done by Bilgili *et al.* (2017) to analyse the effect of urbanization on energy intensity using ten Asian countries namely Vietnam, Bangladesh, Malaysia, Nepal, Thailand, China, South Korea, Indonesia, India and the Philippines. This study employed cross-sectional dependence and heterogeneity test, unit root and cointegration and causality test. The dependent variable of this paper was energy intensity and the independent variables were urbanization, ruralisation, GDP per capita and Squared value of GDP per capita, renewable energy consumption, non-renewable energy consumption and export. This study found that urbanization negatively impacts energy intensity.

Research done by Rafiq, Salim & Nielsen (2016) examined the impact of urbanization, openness and population density on emissions and energy intensity in developing countries. This study used a heterogeneous linear panel model and non-linear panel estimation. This study reveals that urbanization significantly increases energy intensity. Moreover, population density and non-renewable energy consumption also positively influence energy intensity and increase the emission level while renewable energy consumption is insignificant in energy intensity in the research area.

Zhu *et al.* (2021) analysed the impact of urbanization on energy intensity in OECD countries using Generalized Method of Moments (GMM), examined the differences in the impact of urbanization on energy intensity in both energy intensity degree and development level using a heterogeneity test and finally this study corresponded to find the impact of the process of urbanization on energy intensity using an innovation level as a moderating variable. This study has chosen 38 OECD countries as a sample and collected data from 1990 to 2015. This research summarized that urbanization shows a significant U-shaped effect on energy intensity. In addition, this study found that in countries having high energy intensity values, urbanization shows a significant impact, but it does not significantly impact on energy intensity when the countries have lower energy intensities. Finally, this research found that improvement in innovation leads to a negative impact of urbanization on energy intensity.

Elliott, Sun & Zhu (2017) have done a provincial level study for China to find the direct and indirect effects of urbanization on energy intensity using 30 provinces in China. This study employed mean group estimation techniques. This research found that the direct impact of urbanization on energy intensity was positive while the indirect impact of urbanization tends to have negative impacts in China. The indirect impact of urbanization is measured through industrial upgrading, changing lifestyles, construction and transport. The results highlighted that indirect impact of urbanization through construction was higher than other indirect measurement. Koyuncu, Beşer & Alola (2021) also analysed the economic regime with urbanization and energy intensity. This study collected data for Turkey between 1990 and 2015. This study used per capita income, energy intensity and urbanization variables to examine the environmental Kuznets Curve by Threshold Autoregressive Model. Result of this study employed that increasing energy intensity and urbanization obstruct environmental sustainability of the country and income growth lead to decrease environmental degradation.

Shah, Naqvi & Anwar (2020) used the Johnson co-integration and Vector Error Correction Model to find the link between emission, urbanization, income per capita, imports, exports, trade openness and energy intensity in Pakistan based on environmental transition and the ecological modernization theories. The data collected from 1980 to 2017 as a sample. Findings of this research confirm that there is a U shape and dynamic relationship between per capita income, carbon emission and urbanization. This study also corresponded that financial development, inflation and urbanization positively impact the energy intensity. On the other hand, carbon emission, trade openness and labour force participation negatively impact the energy intensity.

The study of Chen & Zhou (2021) explored the relationship between urbanization and energy intensity using 72 countries. Data were collected in this study from 2000 to 2014. The panel threshold method showed that there is a positive relationship between urbanization and energy intensity. However, the quality of the threshold value exceeds energy intensity by 0.033. This study also found that income and energy types impact the institutional threshold and it decreases energy consumption and promotes energy reduction in both OECD and Non-OECD countries. A research done by Aboagye & Nketiah-Amponsah (2016) examined the impact of economic growth, industrialization and urbanization on energy intensity in Sub-Saharan Africa. This study employed the Generalized Method of Moment. This study revealed that urbanization and industrialization positively impact energy intensity while FDI and trade openness negatively impact energy intensity. This study highlighted the existence of the Environmental Kuznets Curve between economic growth and energy intensity.

Lv *et al.*, (2018) have conduct a research to investigate the impact of urbanization on energy intensity by adopting a new technology using 30 provinces in China from 1990 to 2015. This study employed homogeneous-heterogeneous slope with static-dynamic model specifications as an analysing method. This study used economic growth, industrialization and FDI as control variables. The results of this study observed that economic growth and FDI negatively impact the energy intensity while urbanization and industrialization negatively impact the energy intensity.

Further, Farajzadeh & Nematollahi (2018) investigated energy intensity and its components including energy efficiency and structural change in Iran. This study focused regression analysis through multilayer perceptron and wavelet-based neural networks. This study highlighted that non-linear relationship between energy intensity and capital-output ratio as well as income. Nonetheless, insignificant results observed the impact of trade and energy price index on energy intensity. In case of urbanization, it negatively impacts the energy intensity. Rudenko & Tanasov (2022) applied cointegration regression method to find out the long-term relationship between energy intensity and its determinant in Indonesia between 1990 and 2016. This study examined the impact of industry value added, FDI, domestic credit to the private sector, share of nuclear energy and real price of crude oil. According to the finding of this study, industrialization and globalization positively impact the energy intensity. At the same time energy intensity is negatively determined by financial development, energy consumption and price of crude oil.

According to literature, rapid urbanization is a crucial contribution factor on energy intensity. Understanding energy intensity is important to implement the policies to achieve sustainable development. In addition, there are no empirical studies in Sri Lanka related to energy intensity. Therefore, the objective of this study is to examine the effect of urbanization on energy intensity in SAARC countries and then compare Sri Lanka's status with other SAARC countries. Empirical evidence in this study reveals the mixed impact of urbanization on energy intensity in the world. Aboagye & Nketiah-Amponsah (2016), Koyuncu, Beşer & Alola, (2021), Elliott, Sun & Zhu, (2017), Shah, Naqvi & Anwar (2020), Chen & Zhou (2021) and Rafiq, Salim & Nielsen (2016), found a positive impact of urbanization on energy intensity in Sub-Saharan Africa, Turkey, China, Pakistan, both OECD & Non-OECD countries and selected developing countries. At the same time, researches done by Bilgili *et al.*, (2017) in ten Asian countries namely Vietnam, Bangladesh, Malaysia, Nepal, Thailand, China, South Korea, Indonesia, India and the Philippines, Lv *et al.* (2018) in China and Farajzadeh & Nematollahi (2018) in Iran shows a negative impact. Further Liu & Xie (2013) in China, Sadorsky (2013) in 76 developing countries and Zhu *et al.* (2021) in OECD countries found that there is a mixed impact of urbanization on energy intensity.

MATERIALS AND METHODS

Theory

This study used "the Intensity of Energy Use model (IEU)" derived from the "Environmental Kuznets Curve" as a theory. IEU explained the relationship between energy intensity and per capita income like a Kuznets Curve.

This graph indicates that in the early stage of economic growth, energy intensity increases. However, beyond some level of income per capita, energy intensity decreases. Distribution of income, international trade, structural changes, technical progress and improvements in energy efficiency, institutions and governance and consumer preferences, industrialization, globalization and urbanization are the causes of this inverted U-shape (Chima, 2011).

Based on this theory; urbanization, per capita income, squared value of per capita income, capital formation, industrialization, labour, carbon dioxide emission and squared value of carbon dioxide are selected as independent variables and the dependent variable is energy intensity level of primary energy (measurement of energy intensity: MJ / $ (2011 PPP), i.e., megajoules in 2011 USD at purchasing power parity).

Relevance of panel data analysis

A panel data or longitudinal data set consists of time series for each cross-sectional group in the data set (Wooldrige, 2013). This study analyses the impact of urbanization on energy intensity in selected SAARC countries, namely, Bhutan, Bangladesh, Nepal, India, Pakistan and Sri Lanka for the 1990-2015 period. For this study we collected data for 26 years. Therefore, it is a balanced panel data set since each country has observations for 26 years.

Advantages of panel data are more accurate inference of model parameters, greater capacity for analysing the complexity in data, controlling the impact of omitted variables, generating more accurate forecasting for outcomes and less measurement errors. However, panel model has some econometric issues such as autocorrelation, heteroscedasticity and cross-correlation in cross sectional units at the same point over time. Panel data analysis Error Component Model (ECM) namely Fixed Effect Model (FEM) and the Random Effect Model (REM) use to solve those econometric issues.

Fixed Effect Model is commonly used where the individual specific intercept may be correlated with one or more regressors, but it consumes a lot of degrees of freedom (df) when the sample is very large. This model allows to differ among individuals to reflect the unique feature of individual units. This is done by using a group of dummy variables to identify cross sectional units. Therefore, the Fixed Effect Model using dummy variables is called a "Least Squared Dummy Variable model (LSDV)"(Gujarati & Porter, 2009).

In the Random Effect Model, it assumes that the intercept value of an individual unit is a random drawing from a larger population. It is used where the intercept of each cross-sectional unit is uncorrelated with the regressors. Random Effect Model is more economical than the Fixed Effect Model in terms of the number of parameters estimated and also time-invariant regressors can be used in the Random Effect Model. Therefore, if it is assumed that error and regressors are uncorrelated the Random Effect Model is appropriate. But, the Fixed Effect Model can be used when error and regressors are correlated (Gujarati & Porter, 2009). Hausman test is also used to choose the appropriate method between Fixed Effect and Random Effect for the research. According

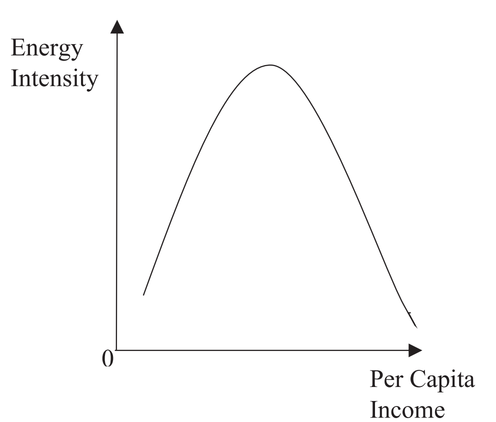

Figure 5: Intensity of Energy Use Model

Source: Chima (2011)

Table 1: Definition of variables

Variable	Variable description, units and hypothesis	Abbreviation used in the equation
Dependent Variable: Log (Energy Intensity)	Energy intensity level of primary energy (MJ/$2011 PPP GDP)	ln(EI)
Independent Variables: Log (Urbanization)	Urban population (percent of urban population) Hypothesis: urbanization has no effect on energy intensity	ln(Urb)
Log (Per Capita Income)	GDP per capita, PPP (current international $) Hypothesis: per capita income has no effect on energy intensity	ln(PCI)
Squared Value of log (Per Capita Income)	GDP per capita, PPP (current international $): Energy intensity has a different effect at higher per capita income levels (compared to low per capita income) Hypothesis: Squared value of per capita income has no effect on energy intensity	Sqrd ln(PCI)
Log (Capital formation)	Gross capital formation (current US $) Hypothesis: Capital formation has no effect on energy intensity	ln(CF)
Log (Industrialization)	Industrial value added (current US $) Hypothesis: Industrialization has no effect on energy intensity	ln(IND)
Log (Labour)	Total labour force Participation Hypothesis: Labour has no effect on energy intensity	ln(L)
Log (carbon dioxide)	Carbon dioxide emission level (Kt) Hypothesis: Carbon dioxide has no effect on energy intensity	ln(C02)
Squared value of log (carbon dioxide)	Carbon dioxide emission level (Kt) Hypothesis: Squared value of carbon dioxide has no effect on energy intensity	Sqrd ln(C02)

Data for required variables were obtained from World Bank data base. Accessed date: 04.06.2021-11.01.2022

to the test, if the computed chi-square value exceeds the critical chi-square value for given degrees of freedom and the level of significance, Fixed Effect Model is more appropriate.

Data

This study uses secondary data from six SAARC countries, namely, Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka. Afghanistan was not included due to non-availability of data. The annual data were collected from the World Bank official website (https://data.worldbank.org/) for the 1990-2015 period (the World Bank data required for the variables of this study is only available from 1990-2015). Each country is treated as a balanced panel and the study uses panel data analysis techniques in econometrics. The variables used in the analysis and their definitions are given in Table 1.

$$ln\,(EI)_{it} = \alpha_1 + \sum_{J=1}^{N} \alpha_i D_j + \beta_1 \ln(Urb)_{it} + \beta_2 \ln(PCI)_{it} + \beta_3 Sqrd\; ln(PCI)_{it} + \beta_4 ln\,(CF)_{it} + \beta_5 \ln(IND)_{it} + \beta_6 \ln(L)_{it} + \beta_7 \ln(Co2)_{it} + \beta_8\, Sqrd\; ln\,(Co2)_{it} + U_{it} \quad (01)$$

$$ln\ (EI)_{it} = \alpha_1 + \sum_{J=1}^{N} \alpha_i D_j + \beta_1 \ln(Urb)_{it} + \beta_2 \ln(PCI)_{it} + \beta_3 Sqrd\ ln(PCI)_{it} + \beta_4 ln\ (CF)_{it} + \beta_5 \ln(IND)_{it} + \beta_6 \ln(L)_{it} + \beta_7 \ln(Co2)_{it} + \beta_8\ Sqrd\ ln\ (Co2)_{it} + U_{it} \quad (02)$$

$$\ln\ (EI)_{it} = (\beta_0 + \alpha_j) + \left[\beta_1 \ln\ (Urb)_{it} + \delta_j\right] + \beta_2 \ln(PCI)_{it} + \beta_3 Sqrd \ln(PCI)_{it} + \beta_4 ln\ (CF)_{it} + \beta_5 \ln(IND)_{it} + \beta_6 \ln(L)_{it} + \beta_7 \ln(Co2)_{it} + \beta_8\ Sqrd\ ln\ (Co2)_{it} + U_{it} \quad (03)$$

Variables and model specifications

This study examines the effect of urbanization on energy intensity in the SAARC region countries by using country wise panel data. Urban population is the proxy variable used for urbanization. To test the hypothesis related to Environmental Kuznets Curve (EKC) the study used two variables i.e., per capita income and the squared value of per capita income which could identify the inverted U shape behaviour of energy intensity with income. The model also includes six country dummy variables to detect country effect. Five other controlled variables are included based on the evidence from the literature that could affect energy intensity. The definitions of the variables used in all models are given in Table 1. The data were analysed using STATA software. Considering the panel data structure in the estimation first model (Equation 1) was estimated using country fixed effects.

Second model (Equation 2) includes country dummies and estimated as an LSDV model. The difference between equations 1 and 2 is LSDV model shows the estimated country coefficients and the fixed effect model does not show it. The second model captures only the differences in energy intensity across countries (differences in the intercept terms). Since Sri Lankan dummy variable was omitted to avoid the dummy variable trap, the coefficients of the remaining country dummies can be interpreted relative to Sri Lanka.

A third model was estimated (Equation 3) to examine how urbanization process has affected countries differently, i.e., differences in the slope coefficients of urbanization between countries.

In addition to the Table 1,

Where,

= Intercept

= Dummy Variables for countries j = *1 .....6*

N= No. of Dummy Variables (06)

= Intercept for countries *j = 1 .....6*

= slope, use to measures the difference in the return to urbanization between countries

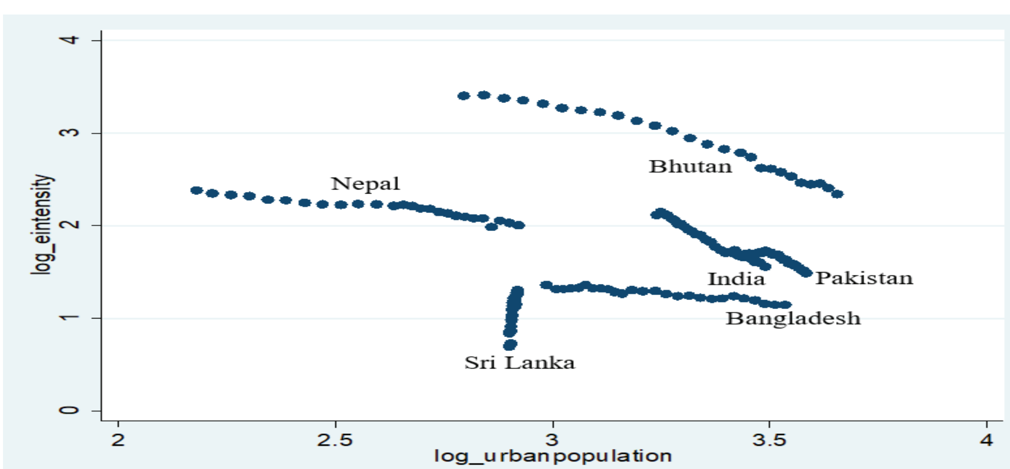

Figure 6: Scatter plot of urbanization and energy intensity

Source: Computed by authors, 2022

Table 2: Summary statistics (1990-2015)

Variables	Mean	Minimum	Maximum	Std.Dev	Skewness	Kurtosis
EI	7.7749	1.993	30.289	6.2907	2.0474	6.7606
Log(EI)	1.8201	0.6896	3.4108	0.6423	0.6667	2.8972
URB	24.703	8.854	38.678	7.5856	-0.1389	1.8651
Log(URB)	3.1532	2.1809	3.6553	0.3128	-0.6851	2.7951
PCI	3178.456	751.8356	11557.49	2252.306	1.6836	5.7898
Log(PCI)	7.856	6.6225	9.3551	0.6374	0.2438	2.4837
CF	7.14E+10	7.75E+07	7.22E+11	1.49E+11	3.2276	12.7947
Log(CF)	23.3386	18.1662	27.305	2.175	-0.5339	2.8794
IND	5.19E+10	6.26E+07	5.75E+11	1.20E+11	3.2343	12.788
Log(IND)	22.6812	17.953	27.0781	2.2501	-0.1179	2.452
L	8.79E+07	214298	4.77E+08	1.48E+08	1.8004	4.487
Log(L)	16.6422	12.2751	19.9837	2.2513	-0.5491	2.6605
Co	221681.3	130	2.15E+06	472803.2	2.5136	8.5872
Log(Co)	9.7918	4.8675	14.5811	2.6018	0.069	2.1466

Observation:156
EI= Energy Intensity; URB= Urbanization; PCI= Per Capita Income; CF= Capital Formation; IND= Industrialization; L=Labour; Co= Carbon dioxide emission
Source: Computed by authors,2022

In the study we used cluster standard error for fixed effect model and other two models used Newey-West standard errors to reduce Heteroscedasticity and autocorrelation.

RESULTS AND DISCUSSION

Descriptive analysis

Annual data were collected from Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka as sample countries for the period from 1990 to 2015. All variables were used in natural log form. The panels are balanced panels which means that all the countries have data for all the years.

Summary statistics are given in Table 2. All vaiables are close to 0 in skewness and it shows that the variables are normally distributed. At the same time, all the variables have less than 3 kurtosis value. Accodingly, these variables are playtikurtic.

The study uses a scatter diagram to explore the relationship between urbanization and energy intensity in six SAARC countries: Bhutan, Bangladesh, India, Nepal, Pakistan and Sri Lanka. The plot reveals a moderately negative linear relationship overall but highlights country-specific differences. India and Pakistan show similar impacts of urbanization on energy intensity, while Sri Lanka deviates due to its unique energy mix and urbanization dynamics. This divergence suggests that Sri Lanka's relationship between urbanization and energy intensity differs significantly from the other nations in the region. Figure 1 shows that urbanization in Sri Lanka increased only slightly between 1990 to 2015, rising from about 15% to just over 18%. This slow growth rate makes it appear almost unchanged in Figure 6 scatter plot. So, urbanization hasn't stopped in Sri Lanka, but it has progressed very slowly compared to other SAARC countries. According to some studies, urban housing cost has gone up in Sri Lanka (Weeraratne, 2020). Higher rental rates as well as property values in urban areas may make urban living less attractive to low- and middle-income populations, which could have contributed to the slower rate of urbanization in Sri Lanka, among other factors.

Regression analysis on energy intensity

The Fixed Effect Model assumes a constant intercept and slopes. This Fixed Effect Model R^2 = 0.9555 implies, that model accounts for 95 percent of the total variance in the energy intensity of SAARC countries. However, variables were not significant except urbanization. To test the differences across countries in energy intensity, this study used the LSDV model incorporating country dummy variables to a Fixed Effect Model. The results of this model are reported in column 03 in Table 3. In the third model, country dummies interacted with urbanization variable in order to examine how urbanization has affected countries differently. Model 01 was estimated using cluster standard error and the other two models were estimated using Newey-West standard errors that do some correction for heteroscedasticity and autocorrelation (Since the model 01 was estimated using fixed effects, STATA doesn't allow to use of Newey-West standard errors. Therefore, this study used cluster standard error in model 01). The Newey standard error is a method for adjusting standard errors in regression models to account for both heteroscedasticity and autocorrelation in the residuals (Newey & West, 1987). The F test accepts all three models. If compared the AIC of LSDV with fixed effect, it chooses the LSDV model. Further, we observe a change in the significance of variables from fixed effect to LSDV as a result of adding country dummies in the second model (Equation 2). The third model in column 04 indicates an even better fit than LSDV model in column 03 with a lower AIC value. There are similarities as well as differences in the results between the two models.

The effect of urbanization in the LSDV model (column 03) and LSDV model with country-urbanization interactive variables (column 04) are somewhat different. The coefficient of urbanization variable in both the models has negative signs; meaning that energy intensity in SAARC countries declines with urbanization. This result is consistent with many studies in the literature (Bilgili *et al.*, 2017 and Elliott, Sun & Zhu, 2017), which could have multiple explanations. Presumably urbanization can change the lifestyle of the people which could affect energy demand. Their daily energy requirements in cooking, heating, cooling and transportation are some items in their energy basket. The net effect of these adjustments seems negative. This means that urban dwellers lower the energy usage in some elements in the commodity basket. For example, a higher concentration of urban population could reduce the energy requirement in transportation. Another possibility is urban people could be more conscious of energy usage. Also, urbanization often leads families to transition from traditional fuels, like firewood which might be typically less efficient to commercial fuels such as LP and natural gas, which offer higher efficiency. For example, in a typical setting of a household where working parents' use of LP gas in cooking is efficient and time-saving compared to the use of firewood. Such changes can contribute to reducing energy intensity, as households adopt more efficient energy sources. Column 04 model indicates that one percent increase in urbanization reduces energy intensity by 4.8935 percent in Sri Lanka (The coefficient of urbanization represents Sri Lanka, since Sri Lanka is considered as the base group for the country dummies. The country-urbanization variable coefficients of the other five countries reflect the difference in the slope compared to Sri Lanka). In the three models, urbanization has the highest effect on energy intensity in the model in column 04 in Table 3.

In order to test the Environmental Kuznets Curve hypothesis (EKC hypothesis) this study used two variables, i.e., per capita income and the squared value of per capita income as in the literature. The per capita income variable is positive and statistically significant at five percent and one percent respectively. The squared value of the same variable is negative and significant at one percent in the second and third models. The signs of these two variables comply with the EKC hypothesis and imply inverted U-shaped behaviour in energy intensity with per capita income for all the SAARC countries. In the third model when per capita income increases by one percent there will be a 0.6360 percent increase in the energy intensity. The squared per capita income variable has a coefficient value of -0.0536, which means that for a one percent increase in this variable, it will decrease energy intensity by 0.0536 percent. This result is consistent with the other studies in the literature, i.e., at the initial level of income energy intensity increases and after some income level it starts declining. This is an important finding for the SAARC region, as rising living standards and income levels in these countries could lead to a decline in energy intensity, thereby contributing to improve the environmental quality standards such as the air quality index. Capital formation variable has somewhat

Table 3: Impact of urbanization on energy intensity

Column -01	Column -02	Column -03	Column -04
Independent variables	Fixed Effect	LSDV	LSDV with country-urbanization interactive variables
Intercept	-0.3452 (2.2149)	-0.6413** (1.606)	22.4245* (6.6897)
Urbanization	-0.4391** (0.1691)	-0.4391* (0.0924)	-4.8935** (2.1797)
Per capita income	0.7984 (0.8124)	0.7984** (0.3749)	0.6360* (0.2381)
Squared of per capita income	-0 0.771 (0.0389)	-0. 0771* (0.0201)	-0.0576* (0.0131)
Capital formation	0.4181 (0.0446)	0.0418*** (0.0246)	0.0079 (0.0130)
Industrialization	-0.1012 (0.0708)	-0.1012** (0.0339)	-0.1091* (0.0198)
Labour force participation	0.0929 (0.0774)	0.0929*** (0.0476)	-0.3507* (0.0650)
Carbon dioxide emission	0.1256 (0.129)	0.1256** (0.0534)	-0.2739* (0.0639)
Squared of carbon dioxide emission	0.0059 (0.0064)	0.0059*** (0.0033)	0.0239* (0.0045)
Bangladesh		-0. 5054* (0.1413)	-14.4923** (6.5530)
Bhutan		2.6663* (0.1643)	-13.3716** (6.4883)
India		-0. 7211** (0.2633)	-8.9958 (6.8316)
Nepal		0.4306* (0.1136)	-13.4981** (6.4668)
Pakistan		-0. 0944 (0.1487)	-18.7590* (6.7781)
Bangladesh*Urbanization			5.0976** (2.2392)
Bhutan*Urbanization			4.7824** (2.2211)
India*Urbanization			3.6354 (2.3276)
Nepal*Urbanization			4.9547** (2.2159)
Pakistan*Urbanization			6.3577* (2.3058)
Number of observations	156	156	156
R squared	0.9555	0.9961	0.9990
AIC (without cluster and Newey-West standard error)	-545.2374	-535.2374	-732.6684
F value		3390.08	13549.59

*- 1 percentage significant level; **- 5 percentage significant level ; ***- 10 percentage significant level respectively: Cluster Standard Error for model 01 and Newey-West Standard Error for models 02 & 03 are given in parenthesis.

different results in columns 02 and 03. It is significant only in column 02. This result between energy intensity and capital formation needs further investigation.

To check the impact of industrialization on energy intensity, this study takes an industrial value added as a measure of industrialization. Industrial sector activities share more energy than the agriculture and service sectors. Therefore, if industrial activities use green technologies, it can reduce the energy intensity. Otherwise, energy intensity will increase. The coefficient of this variable in columns 03 and 04 has almost the same effect on energy intensity. The relationship is negative and significant at five percent and one percent levels. One percent increase in an industrial value-added corresponds to a decrease in energy intensity by 0.1091 percent. This implies industrialization in the SAARC region has shifted towards less energy intensive industries which is a positive development, yet needs an in-depth investigation.

The two models in columns 03 and 04 show a mixed result in labour force participation. The variable has a negative and significant effect on energy intensity in column 04 which is the best fit of all the three models. According to this model, a one percent increase in labour force participation corresponded to a -0.3507 percent decrease in energy intensity. According to literature in SAARC countries, increases the labour force participation leads to increases in the energy intensity while our study finds a different result which needs further investigation.-

Scientific evidence proves that increasing carbon dioxide is a key factor in global warming and other environmental pollution. Result in column 04 indicates U shape behaviour between carbon dioxide and energy intensity when considered the two variables together. This model shows that, one percent increase in CO_2 decreases the energy intensity by 0.2739 percent. The squared value of the same variable indicates one percent increase would increase energy intensity by 0.0239.

Cross country differences in energy intensity and urbanization

Cross country differences were examined using six country dummies where Sri Lanka is considered as the base group in the LSDV model in column 03. The model in column 04, includes both country dummies and country-urbanization interactive variables. Since the best fit according to AIC among all the three models is the model in column 04, we interpret column 04 results in this case too.

In all the five SAARC countries energy intensities are lower than Sri Lanka. This raises the question whether Sri Lanka is the least efficient country in energy usage among SAARC countries. Being a country with high dependency on fossil energy resources, Sri Lanka needs an accelerated action plan to be implemented to bring down the energy intensity. Among all the SAARC countries Pakistan has the lowest energy intensity. The other countries, from the lowest intensity to the highest in the order are, Bangladesh, Nepal, Bhutan and India. The coefficients of four countries namely, Pakistan, Bangladesh, Nepal and Bhutan are statistically significantly different from Sri Lanka. Coefficient of India was not significantly different from Sri Lanka. This implies there is a significant cross-country variation in energy intensity in the SAARC region.

The group of interactive variables indicates that urbanization has differential impact on energy intensity in different countries. Except for India, slope coefficients of the country-urbanization interactive variables in the other four countries (Bhutan, Bangladesh, Nepal and Pakistan) are statistically significantly different from the slope of the same variable in Sri Lanka.

Also, the fact that these interactive variable coefficients being positive is referred to urbanization which has a higher impact in the above four countries compared to Sri Lanka, i.e., rapid urbanization will bring down energy intensity at a faster rate in Sri Lanka.

In this context, Pakistan has the highest rate of increasing energy intensity with urbanization. If we rank the impact of urbanization on other countries from lowest to highest, we find the ranking order of India, Bhutan, Nepal and Bangladesh. Therefore, higher urbanization will have adverse consequences on the environment in these countries due to increased energy intensity.

When compared to Sri Lanka, countries with lower energy intensity may have been affected by some favourable policies adopted by those countries, namely: Bangladesh, Nepal, Bhutan and India. For example, in Bangladesh, Renewable Energy and Energy Efficiency Programme and Country Action Plan for Clean Cookstoves (CAP) were started in 2006 and 2013 respectively (http://www.sreda.gov.bd/). In 1982 India developed a policy that cost-effective PV technology with promotional activities and research and development (Shrestha *et al.*, 2021). Those activities may have helped to reduce energy intensity in Bangladesh and India than in Sri Lanka.

Summary of results and discussion

Based on the model fitting criterion like AIC, we were able to choose the third model as our best fit for the panel data structure. Thus, in addition to the panel-fixed effects procedure, we used LSDV procedure which will give country coefficients. In the three models, sign and the size of the coefficient of urbanization and per capita income variables were consistent. Most of the other main variables (except country dummies) had similar coefficients in all three models. Country dummy coefficients were different in the third model and we chose the third model (column 04) as the best fit for interpretation. Urbanization in the SAARC region increases energy intensity in all the countries except Sri Lanka. However, the effect of urbanization is not the same in all the countries as expected. According to the results of this study urbanization increases energy intensity in Pakistan at the highest rate in the SAARC region. Per capita income and the squared value of per capita income variable results confirm EKC hypothesis in the third model. Industrialization and labour force participation lower energy intensity. Carbon dioxide emission and the squared value of that variable show U-shaped behaviour with energy intensity. According to country dummies, Pakistan has the lowest energy intensity while Sri Lanka has the highest energy intensity.

CONCLUSION AND POLICY RECOMMENDATIONS

The objective of this paper was to examine the impact of urbanization on energy intensity in the SAARC countries. Thus, a lower energy intensity is always preferred in a country's energy policy. It is also a fairly good proxy to compare the energy efficiency at the aggregate energy consumption level, between countries. Many countries face the problem of trade-off between achieving higher economic prosperity with a lower energy intensity. Among many factors that affect energy intensity, urbanization is identified as one of the major factors in the literature. Therefore, this paper focused on estimating the effect of urbanization on energy intensity in the SAARC countries since there were no other studies in this regard. The study used 1990-2015 annual data for the SAARC countries. Due to the panel structure in the data this study used the fixed effects model, LSDV model and LSDV with country-urbanization interactive variables model (Table 3, column 04). The fixed effects and the LSDV model results were the same. The reason to estimate the LSDV model is to obtain the country dummy variable coefficients for comparison across countries which hides in the fixed effects model.

Overall results from the three regression models indicate that the best fit of the three models is the LSDV model with country-urbanization interactive variables. This model includes eight control variables, five country dummies and five country-urbanization interactive variables while considering Sri Lanka as the base group. According to the results of LSDV model with country-urbanization interactive variables, cross-country comparison indicates that there is a significant variation in energy intensity in the SAARC region. Sri Lanka has the highest energy intensity and Pakistan has the lowest. The other countries, from lowest intensity to highest in the order are Bangladesh, Nepal, Bhutan and India. This implies that Sri Lanka uses the highest amount of energy to produce a unit of GDP in the SAARC region. Accordingly, among the SAARC countries Sri Lanka is not efficiently using the energy.

Our key variable urbanization indicates differential effects in SAARC countries. It lowers energy intensity in Sri Lanka, which is a piece of good news. Rapid urbanization will bring down energy intensity at a faster rate in Sri Lanka. In this context, Pakistan has the highest rate of increasing energy intensity with urbanization. If we rank the impact of urbanization on other countries from lowest to highest, we find the ranking order of India, Bhutan, Nepal and Bangladesh. Higher urbanization will lead to adverse environmental consequences. These countries need high profile coordinated government intervention to lower the impact of urbanization to move toward lower energy intensity in the long run. Our analysis with the help of country-urbanization interactive variables was able to show that the effect is not constant across countries. Many studies in the literature estimate a constant country effect of urbanization, which will yield poor estimates given the heterogeneous nature in the economies. Analysis in this study is helpful to introduce integral country-specific policy measures in both urban and energy use planning to identify the level of effort that each country has to put. Such efforts will help to achieve sustainable economic prosperity in the long run by mitigating adverse consequences of higher energy intensity.

In the context of Sri Lanka, this is vital since the country is entirely importing fossil energy resources and products which account for USD 3.7 billion. Sri Lanka has the potential to lower the energy intensity by cutting down the energy use especially in the transportation sector. Particular attention can be given to improving the conditions in the public transportation which will cut down our energy consumption significantly. The PCI variable together with the squared value of PCI results comply with the EKC hypothesis as in the literature. In the SAARC region, India too has to give higher attention to achieving higher energy efficiency and lower energy intensity since India ranks next to Sri Lanka in terms of inefficiency in energy consumption (being the second highest country in energy intensity).

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Appendix I: Energy Intensity in SAARC countries from 1990-2015 (MJ / $ (2011 PPP)

Year	Bhutan	Bangladesh	India	Nepal	Pakistan	Sri Lanka
1990	30.0153	3.89947	8.2916	10.7913	5.46013	3.68928
1991	30.289	3.71422	8.54837	10.4738	5.32913	3.58036
1992	29.3292	3.71804	8.40019	10.3058	5.27022	3.51902
1993	28.5173	3.74897	8.21116	10.1858	5.44234	3.47052
1994	27.5679	3.76898	7.99411	9.74633	5.46182	3.15595
1995	26.3128	3.90083	7.85816	9.71617	5.43487	3.08816
1996	25.6503	3.75414	7.53016	9.44647	5.45533	3.32932
1997	25.1515	3.75324	7.52418	9.28322	5.54413	3.24261
1998	24.3211	3.72007	7.25604	9.2455	5.52327	3.14843
1999	22.858	3.60124	7.05055	9.342	5.62594	3.22343
2000	21.7941	3.53894	6.94959	9.28628	5.54025	3.34922
2001	20.4761	3.68413	6.72481	9.15264	5.52118	3.28862
2002	18.9806	3.63289	6.672	9.24301	5.40881	3.22147
2003	17.7911	3.65484	6.33392	9.14376	5.39291	3.22045
2004	16.8308	3.53715	6.18111	8.86063	5.38477	3.09498
2005	16.2144	3.44757	5.87752	8.85274	5.18595	2.98024
2006	15.5068	3.4628	5.66185	8.56398	5.0881	2.79317
2007	13.7379	3.37924	5.50765	8.44205	5.11363	2.66663
2008	13.6392	3.34562	5.56214	8.23468	4.94368	2.47724
2009	13.2004	3.35071	5.64671	8.11063	4.87983	2.37458
2010	12.5511	3.43732	5.35318	7.96568	4.87212	2.36731
2011	11.7594	3.34942	5.23299	7.97206	4.77747	2.34441
2012	11.5601	3.29958	5.19964	7.27267	4.66899	2.31163
2013	11.6454	3.17849	4.98863	7.76571	4.58216	1.99298
2014	11.0602	3.12944	4.96015	7.6037	4.53627	2.03284
2015	10.4079	3.13981	4.73091	7.42383	4.42216	2.06413

Source: World Bank open data, (1990-2015)

In this paper, energy intensity is measured as the ratio between energy consumption and GDP, expressed in MJ per $2011 PPP GDP, which is directly sourced from https://databank.worldbank.org/source/sustainable-energy-for-all/Series/6.1_PRIMARY.ENERGY.INTENSITY - Accessed: 04.06.2021

Appendix II: Hausman test to check the reliability of fixed effect model

In order to select the dependable regression between fixed effect and random effect, the model employed the Hausman test. According to this test, if the null hypothesis is rejected, it leads to the conclusion that the random effect is unsuitable due to potential correlations between the random effects and one or more regressors. Consequently, in such instances, the fixed effect becomes more suitable for conducting panel data analysis (Gujarati & Porter, 2009).

According to that, hypothesis for Hausman test and results given below,

Ho: Random effect model is appropriate

H1: Fixed effect model is appropriate

	(b)fe	(B) re	(b-B) Difference	sqrt(diag (V_b-V_B)) S.E.
log_pci	.798389	-1.51542	2.313809	.1481929
log_cforma~n	.0417959	.228905	-.187109	.0215909
log_indvalue	-.1011917	-.3801916	.279	.0014422
log_labour	.0928909	-.4552884	.5481793	.
log_co	.125591	-.4355446	.5611355	.
log_urbanp~n	-.4391358	.5066983	-.9458341	.0701244
log_pci_sq~d	-.0770621	.0618442	-.1389062	.
log_co_squ~d	.0059355	.0419315	-.035996	.0023415

b = consistent under Ho and Ha; obtained from xtreg B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic chi2(8) = (b-B)'[(V_b-V_B)^(-1)](b-B) = 414.13

Prob>chi2 =0.0000

(V_b-V_B is not positive definite)

According to the results, Probability value of Hausman test is 0.000, therefore, null hypothesis rejected and alternative hypothesis accepted that fixed effect model is appropriate than random effect for this research.