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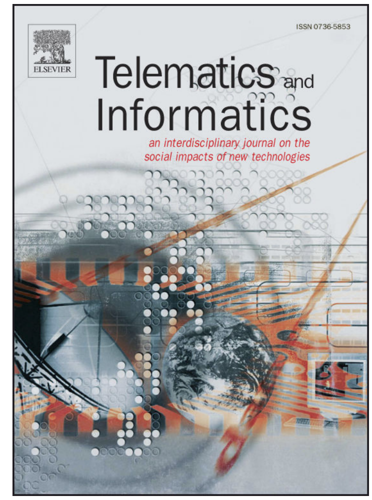

The effect of ICT on energy consumption and economic growth in South Asian economies: An empirical analysis

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The effect of ICT on energy consumption and economic growth in South Asian economies: An empirical analysis

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Abstract

This study contributes to the literature by analyzing the effects of information and communication technology (ICT) on economic performance and energy consumption of selected South Asian economies i.e. Bangladesh, India, Pakistan and Sri Lanka for the period of 1990-2018. For empirical analysis, we employed the bounds testing approach of cointegration and error correction modelling. The findings of the study confirm that, in the long-run, ICT significantly and positively contributed to the economic growth of India only. Similarly, India is the only country in South Asia that has achieved energy efficiency as a result of increased use of ICT. However, energy consumption proved to be an important determinant of GDP per capita in India and Pakistan. Also, GDP per capita has a positive and significant impact on energy consumption in both India and Pakistan. These results imply that South Asian economies try to follow their regional partner, India, in increasing the role of ICT in their economies, which on one side will boost their economic growth and on the other side will help them in achieving energy efficiency. Moreover, the energy conservation policy could prove detrimental to South Asian economies.

Keywords: ICT, Economic growth, Energy consumption, South Asia, ARDL

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Abstract

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Keywords: ICT, Economic growth, Energy consumption, South Asia, ARDL

Commented [S1]: Comment 1 addressed

Commented [S2]: Alphabetically arranged as pointed in comment 4.

1. Introduction

The vast internet spread over the last 20 years has changed the dynamics of human life by changing it into a digital lifestyle (Moyer and Hughes, 2012). This revolution has transformed the way of looking at things as books, compact disks, snapshots, and chequebooks transferred into bytes, Moving Pictures Expert Group-Audio Layer 3 (MP3s), Joint Photographic Experts Group (JPGs), and clicks respectively. Moreover saving time, money, and resources have become possible through effective utilization of online shopping, e-commerce, teleconference, and teleworking (Sui and Rejeski 2002). This shift from physical resources to information resources may have a significant positive effect on environmental quality and energy consumption which is an indicator of less capital demanding and weightless economy (Toffel and Horvath, 2004). The reduction of resource and pollution concentration for economic growth is anticipated due to the above-mentioned transformation. Few examples; teleconference, teleworking, and online shopping benefit in the form of a decrease in travel and shopping-place gatherings which result in reduced fuel consumption and eventually will lower CO_2 emissions (Romm, 2002). Moreover, e-commerce as a whole produces waste in less quantity instead of hardcopy letters it uses pixels based printing catalogues (Coroama et al., 2015; Fuchs, 2008). Devices like laptops, tablets, and LCDs have increased their efficiency in energy consumption and are decreasing their sizes constantly, however, enhancement in demand for such devices cause an increase in energy consumption of their associated technologies (Heddeghem et al. 2014). According to Salahuddin and Alam (2015), electricity consumption due to information and communication technology (ICT) devices is increasing at the rate of 7% per year, while production and usage of ICT related devices are responsible for 1% to 3% global CO_2 emission (Houghton 2010; Peng 2013).

Commented [S3]: Comment 3 addressed

Commented [S4]: First time we have completely written the name of ICT and then use acronym for it.

In the last two decades, electricity demand due to ICT usage has been drastically amplified at the workplace and households (Ahmed and Ozturk, 2018). ICT has the ability to create compensation effects against the substitution effects (Cho et al. 2007). Especially installations and operation of ICT devices & equipment which need high energy and result in increasing electricity demand. The rate at which electricity consumption intensified due to ICT equipment i.e. communication network, personal computers and data center is nearly 7% per year, which contributes to 3.9% in 2007 to global electricity consumption and 4.6% in the year 2012 (Salahuddin et al,2016, Van Heddeghem et al 2014). However, the increased electricity consumption due to extensive use of ICT products might be offset by the energy-efficient role of ICT and hence, reduces the electricity demand. In this regard, “IT for green” is a term that could be useful to tell the greyish dimension of IT (Peng 2013; Salahuddin et al. 2016). Cai et al. (2013) and Dedrick (2010) used a phrase “IT for Green” which states that IT sector has potential to reduce CO_2 emission by using more energy-efficient resources across different economic sectors(Ahmed et al. 2020). To gain more viable future progress and satisfactory level of carbon footprints, the ICT sector needs to focus on more eco-friendly devices with the least carbon footprints of their own. After the emergence of sustainable development concepts in the 1980s, the mutual consensus across countries has been raised to reduce energy consumption through increased development in the field of ICTs (Sadorsky, 2012; Salahuddin and Alam, 2015). The development of ICTs has the capability of decreasing the demands of energy and significantly enhancing economic growth (Walker, 1985). As the ICT industry is growing faster, it must influence energy consumption. Researches have been conducted to investigate whether the impacts of ICT on energy consumption are positive or negative, how it can be helpful to achieve goals of sustainability.

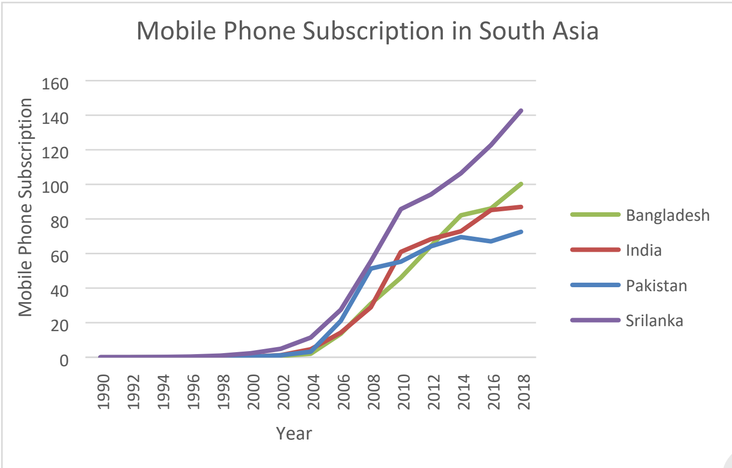
Due to rapid population and urbanization, the energy demand in many developing countries has been increasing continuously in recent years. Most of the world's developed & developing countries are striving toward internet-based economies, as the ICT revolution is going to have a positive effect on future economies. As per the report of International Energy Agency (IEA,2013), the energy demand of emerging economies like China, India, and Middle Eastern countries has been multiplying the world energy demand, which clearly shows the energy demand boost in these regions as compared to existing developed countries. At the same time, these emerging markets are responsible for the increased global CO_2 emission levels and are amongst the world's largest carbon emitters. Among the major users of ICT devices in the world are China and India (Osorio et al., 2013). There is a rapid increase in the number of internet users in China from 1% to 50% in 1990 and 2015 respectively and 26% increase in India in the same period (World Bank, 2017).

South Asian region is one of the most densely populated areas of the world and it is home to almost one-fourth population of the world. The countries in this region are developing economies and the involvement of ICT in these countries is on increasing since the mid-1990s. Trends of ICT, GDP per capita, and electricity consumption for India, Pakistan and Sri Lanka over the period 1990-2018 are shown in Figure 1. However, for Bangladesh, this trend is shown for the period 1992-2018. Hence, in this study we have picked the South Asian region, to see what effects ICT have on the electricity consumption and GDP per capita of South Asian economies. To that end, we have shortlisted four largest economies of South Asia which are India, Pakistan, Bangladesh, and Sri Lanka as the large enough continuous data were only available for these countries. Previously, researchers have included these countries in their studies however; they used panel data which have a problem of aggregation bias and cross-sectional dependence. Therefore, we can say that this is the first-ever study in which time series analysis is being performed on South Asian economies with regards to the impact of ICT on electricity consumption and GDP per capita.

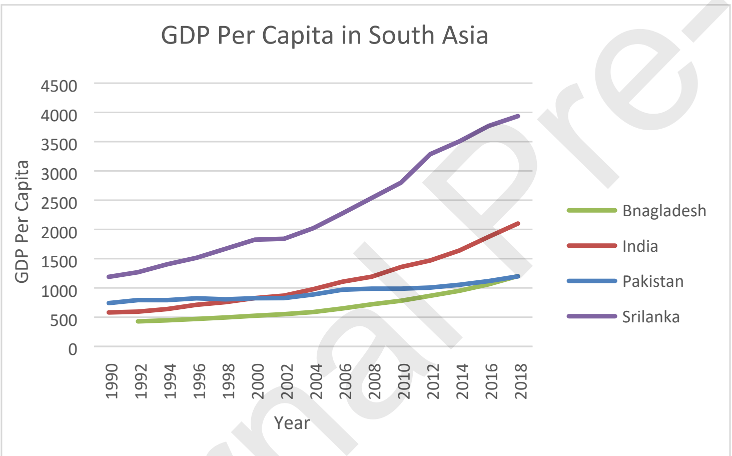
This study is divided into five sections. In the next section brief review of previous studies has been provided. Data, model, and methodology are discussed in section 3 of the study. We have discussed the results of our empirical analysis in section 4. Lastly, the conclusion is provided in section 5.

Figure 1: Trend of the variables

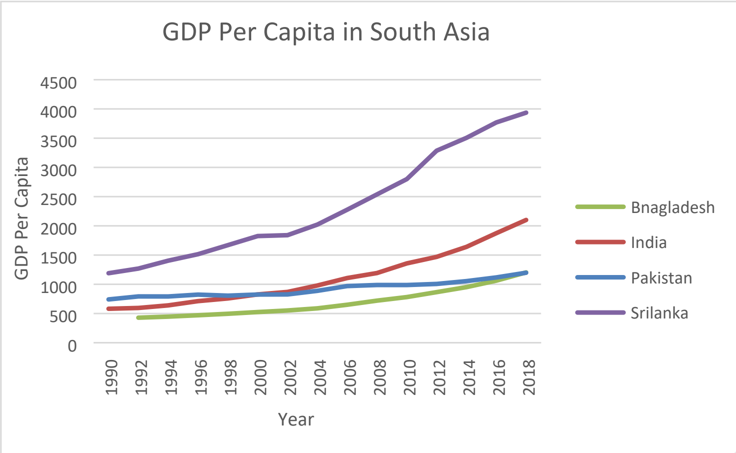
Commented [S5]: Alphabetically arranged



Mobile Phone Subscription in South Asia
Mobile Phone Subscription
0
20
40
60
80
100
120
140
160
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year
Bangladesh
India
Pakistan
Srilanka



GDP Per Capita in South Asia
GDP Per Capita
0
500
1000
1500
2000
2500
3000
3500
4000
4500
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
Year
Bnagladesh
India
Pakistan
Srilanka



2. Literature review

2.1. ICT and its impact on economic growth

Researches to find out the link between ICT and economic growth started in 1960 but most of the studies have been conducted in the USA mainly. Static data used by Jipp (1963); Gilling (1975); Hardy (1980); Saunders et al. (1983) and they concluded that there is a positive correlation between ICT and economic growth. But they didn't figure out the long-run equilibrium amongst various variables included in the study, therefore the actual contribution of ICT in economic growth is difficult to state. Romm (2002) used the term "internet economy" for the US economy which is being escalated by huge economic growth, in one of his most cited studies about impacts of ICT on energy demand and consumption. In his research, he also introduces a concept of "New Energy Economy" which states that increased use of the internet leads to economic growth with less energy consumption but it might have significant environmental impacts.

Najarzadeh et al. (2014) used panel data of 108 countries and studied the impact of the internet on labor efficiency from 1995-2010. He found out the strong substantial relationship between internet usage and labor productivity by using empirical exercise. Elgin (2013) investigated the effect of the internet on the shadow economy by using panel data of 152 countries from 1999 to 2007. In his study, he used cross country regression and found that there is a strong link between internet usage and shadow economy and it has an influence on GDP per capita. He further highlighted two contrasting effects of internet usage, increase in productivity effect which resulted in a reduction of the size of the shadow economy, and the other one was by increasing tax-dodging effect which amplified the size of the shadow economy. These conclusions were tough to implement due to different econometric specifications.

The literature review on the topic shows that many empirical studies have been conducted to examine the impact of ICT on economic growth and they conclude that ICT is one of the main contributors to enhancing economic growth. Some other studies have evaluated the effect of ICT on economic growth by keeping other factors of growth constant, and results showed that ICT is one of the major driving forces of an increase in economic growth. Several pieces of research have been conducted to figure out the level of casual linkage between ICT and economic growth. These studies concluded that ICT is one of the reasons and consequences of economic growth 27 countries of eastern and central Europe were considered for the analysis of the empirical relationships among economic growth and investment for the period of 1990-95 by Madden and Savage (1998). A positive relationship was observed in the study; among investment in telecommunication infrastructure and economic growth. A group of 25 OECD countries for the period of 1996-2007 were also analyzed for the outcome on economic growth due to the development of broadband infrastructure, by Czernich et al. (2014) which showed a positive result. An annual 0.9-1.5% per capita growth in GDP can be obtained with a 10% increase in broadband penetration based on the author's results. A study showing the effects of ICT indicators on economic growth over the period 1980-2015 for 149 countries was carried out by Majeed and Ayub(2018). It was observed that ICT infrastructure mainly affects economic growth. The effect of telecommunication infrastructure development on the economic growth of 40 sub-Saharan African countries while using panel data for the period 2006-15 was carried out by Haftu(2018). The author concluded that the per capita income of the region will have a positive impact on an increase in ICT in the shape of mobile phone subscribers in the selected period.

2.2. ICT and energy consumption

German mobile telephone sector consumes 7% of the total energy of the country excluding the charging of handsets, the same goes to 45% when the charging of handsets is also included (Schefer et al., 2003). The effects of ICT investments and energy costs on industrial electricity demand of South Korea were inspected through time-series data analysis by Cho et al. (2007). ICT investment causes a rise in electricity intensity in the services and the manufacturing sector which has a bit higher consumption of electricity basing on their findings. In order to enhance electricity efficiency in the services sector additional efforts to be put in, is also suggested. Several time series studies by adding a proxy for ICTs, have been carried out about effects of ICTs on energy requirements (Cho et al. 2007; Collard et al. 2005; Ishida 2015; Romm 2002; Ropke et al. 2010; Sadorsky 2012; Salahuddin and Alam 2015; Takase and Murota 2004). Over three decades (1980-2010) analysis for Japan was conducted by Ishida (2015) to gauge a long-run correlation among ICT, energy consumption, and economic growth. A moderate reduction in energy consumption was observed by using ICT investments in his analysis. Both long & short-run effects of the usage of the internet and economic rise on the consumption of electricity in Australia from 1985 to 2012 were analyzed by Salahuddin and Alam (2015). Internet use increases electricity consumption, as well as a unidirectional casualty running from internet usage to electricity consumption, was observed by them. A logistic growth model for the period of 1991-2003 was used by Cho et al. (2007) for analysing the effects of ICT investment on the electricity consumption for South Korean industries. Findings of the study demonstrated that electricity consumption was increased in five sectors and a decrease was observed only in the manufacturing sector. Changes in CO2 emissions and energy consumption in the USA and Japan by the use of IT investments were examined by Takase and Murota (2004). As per their analysis due to IT investments, energy consumption may get increased in the USA however may get decreased in Japan. Similarly, Ahmed and Ozturk (2018) explored that increased use of the latest technology may intensify the energy consumption in long-run by 0.4% in China. The study period ranged from 1985-2013 and the technique adopted by the study was autoregressive distributed lag (ARDL) model.

Another set of dynamic data studies are (Sadorsky 2012; Saidi et al. 2015; Tunali 2016; Wang and Han 2016). As per Sadorsky (2012) in 19 of the emerging economies over the period 1993-2008 an increase in the electricity consumption was observed due raise in ICTs however as per Saidi et al. (2015) an enhanced and statistically significant impact of ICTs was observed on electricity consumption on the collection of data from 67 countries of the world. Other groups of studies are focused on ICTs effects on environmental quality. Travel related GHG emissions reduced to 50% by using teleconferences as per Coroama et al. (2012); as well as another energy-efficient mean is video conferencing as compare to its old-fashioned counterparts Coroama et al. (2015). As per analysis of Chavanne et al.'s (2015) electricity can be significantly saved by the use of teleconferencing. The effects of wireless technologies are lesser than the customary technologies Toffel and Horvath (2004). Ecommerce logistics proved to be cheap and have less environmental effects as compared to customary retailing (Matthews et al., 2001).

3. Data and Methodology

3.1. Data

We have targeted South Asian countries in this study and selected four top economies of South Asia, as the data on the ICT variable for rest of the countries in this region is not long enough for the application of time series analysis. Data has been taken from 1990-2018 for India, Pakistan, and Sri Lanka. However, the data span for Bangladesh covers the period from 1992-2018. The foremost objective of our study is to check the impact of ICT on GDP per capita constant 2010 US$ (GDPP) and electric power consumption kilowatt-hour per capita (EC) in selected South Asian economies. Electric power consumption is used as proxy energy consumption in South Asian economies and henceforth, in this study, we will call it energy consumption. Data on energy consumption have few missing values from the year 2015-2018 for all countries and these missing values are replaced by the generated values using linear interpolation. Moreover, most of the previous studies have used internet users per 100 people as a proxy of ICT. However, in case of South Asian economies data on internet users is not long enough to be used in time series analysis hence, we have

Commented [S6]: Comment 2 addressed

used mobile cellular subscriptions per 100 people as a proxy of ICT as suggested by the studies like Sadorsky (2012), Saidi et al. (2015), Salahuddin and Alam(2016), and Inani and Tripathi (2017). Trade openness (TO) which is used as control variables is defined as a ratio of total trade volume of a country to its GDP. Data on all variables have assembled from World Development Indicators. Descriptive statistics are presented in Table 1.

Table 1: Descriptive statistics

Commented [S7]: Alphabetically arranged and rearranged the results up to 3 decimal points.

		LnGDP	LnEC	LnICT	LnTO
Bangladesh	Mean	6.488	5.088	0.295	3.501
	Median	6.426	5.171	1.868	3.538
	Maximum	7.093	5.975	4.608	3.876
	Minimum	6.061	4.101	-8.371	2.992
	Std. Dev.	0.318	0.603	4.334	0.245
	Observations	27	27	27	27
India	Mean	6.929	6.204	0.466	3.485
	Median	6.887	6.113	1.531	3.624
	Maximum	7.651	6.874	4.470	4.021
	Minimum	6.355	5.606	-6.732	2.741
	Std. Dev.	0.402	0.380	3.815	0.403
	Observations	29	29	29	29
Pakistan	Mean	6.813	5.993	0.614	3.491
	Median	6.789	6.023	1.165	3.495
	Maximum	7.088	6.289	4.284	3.661
	Minimum	6.608	5.626	-6.288	3.231
	Std. Dev.	0.138	0.172	3.569	0.116
		29	29	29	29
Sri Lanka	Mean	7.674	5.797	1.648	4.185
	Median	7.612	5.870	2.434	4.266
	Maximum	8.278	6.302	4.960	4.484
	Minimum	7.081	5.020	-5.144	3.836
	Std. Dev.	0.383	0.428	3.158	0.209
	Observations	29	29	29	29

3.2. Models and Methodology

Following the studies like Sadorsky (2012), Ozturk and Mulali (2015), Ishida (2015), and Salahuddin and Alam (2015) we have constructed the following growth and energy models.

$$LnGDP_{i,t} = a_0 + a_1 LnICT_{i,t} + a_2 LnEC_{i,t} + a_3 LnTO_{i,t} + \mu_{i,t} \text{----------------}(1)$$

$$LnEC_{i,t} = b_0 + b_1 LnICT_{i,t} + b_2 LnGDP_{i,t} + b_3 LnTO_{i,t} + \mu_{i,t} \text{----------------}(2)$$

Equation (1) is a growth model and, GDP in selected South Asian economies is determined by mobile cellular subscriptions per 100 people (ICT), energy consumption kWh per capita (EC), and a measure of trade openness (TO). Specification (2) represents the energy model in all selected countries. While subscript i represents each country whereas, t represents time in both models. $\mu_{i,t}$ is normally distributed error term. Models are expressed in the forms of natural logs. If the variables are a mixture of I(0) and I (1) as in our case we can apply the bounds testing methodology of cointegration and error correction modeling approach proposed by Pesaran et al. (2001) and accordingly we rewrite the specifications (1 & 2) in error correction format as given below:

$$\Delta \mathrm{Ln\ GDP}_{i,t} = \alpha_0 + \sum_{i=1}^{n1} \alpha_{1i} \Delta \mathrm{LnGDP}_{i,t-i} + \sum_{i=0}^{n2} \alpha_{2i} \Delta \mathrm{LnICT}_{i,t-i} + \sum_{i=0}^{n3} \alpha_{3i} \Delta \mathrm{LnTO}_{i,t-i} + \sum_{i=0}^{n4} \alpha_{4i} \Delta \mathrm{LnEC}_{i,t-i} + \eta_1 \mathrm{LnGDP}_{i,t-1} + \eta_2 \mathrm{LnICT}_{i,t-1} + \eta_3 \mathrm{LnTO}_{i,t-1} + \eta_4 \mathrm{LnEC}_{i,t-1} + \varepsilon_{i,t} \quad ------(3)$$

$$\Delta \mathrm{Ln\ EC}_{i,t} = \beta_0 + \sum_{i=1}^{n1} \beta_{1i} \Delta \mathrm{LnGDP}_{i,t-i} + \sum_{i=0}^{n2} \beta_{2i} \Delta \mathrm{LnICT}_{i,t-i} + \sum_{i=0}^{n3} \beta_{3i} \Delta \mathrm{LnTO}_{i,t-i} + \sum_{i=0}^{n4} \beta_{4i} \Delta \mathrm{LnGDP}_{i,t-i} + \pi_1 \mathrm{LnEC}_{i,t-1} + \pi_2 \mathrm{LnICT}_{i,t-1} + \pi_3 \mathrm{LnTO}_{i,t-1} + \pi_4 \mathrm{LnGDP}_{i,t-1} + \varepsilon_{i,t} \quad --(4)$$

Specifications (3 & 4) are ARDL forms of our GDP and energy models and give short-run and long estimates through a single equation. The coefficients attached with differenced (Δ) indicators represent short-run results. On the other side, the coefficients η_2-η_4 normalized on η_1 depict long-run results in equation (3) while, the long-results in equation (4) are represented by coefficients π_2-π_4 normalized on π_1. However, the long-run results are valid if we can prove the joint significance of lagged level variables by applying F-test offered by Pesaran et al. (2001). Pesaran et al. (2001) developed critical values for this F-test but they only suit large samples and our sample is not large enough, therefore, we trust the critical values of Narayan (2005). If the calculated value of the F-test is greater than the upper bound critical value this confirms the legitimacy of our long-run estimates or in other words approves that our long-run results are cointegrated.

4. Results and discussion

Before the start of empirical analysis, we need to select an optimum number of lags. To that end, we have applied the maximum of two lags as our data is annual and total observations are 29[1]. To select a suitable number of lags we apply Akaike Information Criteria (AIC). The results of stationary tests are reported in Table 2. From the stationary tests of Dickey-Fuller Generalized Least Square (DF-GLS) and Phillips Peron (PP), we found that none of the variables is I (2). However, few of the variables are stationary at a level whereas, some are stationary at first difference. The results of both GDP and energy models are furnished in Table 2.

Table 2: Unit root

Commented [S8]: Alphabetically arranged

	Ln EC		Ln GDP		Ln ICT		Ln TO	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
Bangladesh								
DF-GLS	-0.110	-5.131***	0.287	-0.639	-0.635	-2.486**	-1.213	-4.393***
PP	-0.947	-5.230***	-7.270***	-0.615	-4.179***		-2.138	-5.030***
India								

[1] Hakkio and Rush (1991) observed that cointigeration is a long-run concept which require long span of time instead of large number of observations and 29 annual observations mean 29 years which is quite a long span of time.

DF-GLS	0.204	-3.181***	-0.324	-2.901***	-2.291**		-0.711	-4.361***
PP	0.671	-3.376**	5.877	-5.002***	-2.383	-5.386***	-1.914	-4.509***
Pakistan								
DF-GLS	-0.053	-4.679***	0.582	-2.956***	0.239	-2.096**	-1.552	-5.641***
PP	-1.354	-5.006***	0.749	-2.915*	-2.591	-3.629**	-1.894	-5.841***
Sri Lanka								
DF-GLS	-2.010**		-0.518	-3.918***	-0.787	-3.074***	-0.714	-4.565***
PP	-3.137**		0.003	-3.992***	-6.519***		-0.748	-4.448***

From short-run estimates of GDP model, reported in Table 3, we gather that increased use of ICT has contributed positively and significant in the economic growth of Bangladesh and India and the size of the estimate of D(ICT) is 0.006% for Bangladesh and 0.012% for India. Hence, we can infer that in the short-run the ICT has a very minuscule impact on the economic wellbeing of people of India and Bangladesh and in the rest of the South Asian economies i.e. Pakistan and Sri Lanka this effect is not even visible. However, the estimates attached to D(EC) are significant in the case of India, Pakistan, and Bangladesh suggesting that electricity consumption has played an important role in increasing per capita income in South Asian economies except for Sri Lanka. For example, 1% increase in electricity consumption will lead to an increase 0.037% GDP per capita in Bangladesh, in the case of India this increase in GDP per capita is 0.283% and for Pakistan, this increase is 0.252%. Estimates of trade openness (TO) are insignificant in the case of India, Pakistan, and Sri Lanka whereas, 1 % increase in TO have positively impacted the economic activity of Bangladesh by 0.026%.

From Panel B, we infer that in long-run the LnICT variable carries a significant coefficient estimate in the only country i.e. India. From this result, we can infer that as the use of ICT in India surges by 1% it puts a positive impact on the economic growth of India by 0.039%. In the rest of the countries, the contribution of ICT in economic growth is insignificant. Similarly, increasing trade activities do not play any significant role in boosting the economic activities of Bangladesh, India and Pakistan. Astoundingly, the enhanced trade activities in Sri Lanka by 1% reduced the per capita income of Sri Lanka by 0.589%. The long-run estimates attached to LnEC are significant in the case of India and Pakistan, implying that the 1% increase in electricity consumption improves the economies of both India and Pakistan by 0.886% and 1.241% respectively. The validity of the long-run results is conditional on the significance of F-statistics reported in Panel C along with other diagnostic statistics. From seeing Panel C, we can confirm that F-statistics are significant for Bangladesh, India and Sri Lanka as in these countries the F-statistics values are greater than the critical value of 4.15(5.01) at 10%(5%) level of significance. These critical values come from Narayan (2005) due to our small sample size. In the remaining country Pakistan we shift our focus to the estimates of ECM_{t-1}, an alternative way to prove cointegration if the estimate attached to ECM_{t-1} is negative and significant. From Panel C, we confirm the negative and significant estimates of ECM_{t-1} in the case of Pakistan.

Table 3: ARDL short and long-run estimates

Commented [S9]: Alphabetically arranged

	Bangladesh		India		Pakistan		Sri- Lanka	
Dep var:	**GDP**	**EC**	**GDP**	**EC**	**GDP**	**EC**	**GDP**	**EC**
Panel A: Short run								
D(Ln ICT)	0.001	0.016	0.012**	-0.023**	-0.003	0.047	0.010	0.037**
	(0.078)	(0.490)	(1.966)	(3.073)	(1.124)	(1.501)	(0.893)	(2.496)
D(Ln ICT(-1))	0.006**	-0.076**						
	(2.087)	(2.351)						
D(Ln TO)	0.026**	-0.029	-0.041	0.068	0.000	-0.142**	0.041	0.184**
	(2.499)	(0.244)	(1.230)	(1.406)	(0.002)	(2.192)	(0.853)	(2.044)
D(Ln TO(-1))		0.350**		-0.097*			0.068	
		(2.389)		(1.883)			(1.373)	
D(Ln EC)	0.037**		0.283**		0.252**		0.101	
	(2.358)		(2.731)		(4.264)		(1.236)	
D(Ln GDP)		1.723		0.446**		1.310**		0.838**
		(0.695)		(2.746)		(3.765)		(2.048)
D(LnGDP(-1))		-4.086**						
		(1.998)						
Panel B: Long run								
Ln ICT	-0.181	0.359	0.039**	-0.057**	-0.013	0.008	0.040	0.106**
	(0.441)	(0.308)	(3.140)	(3.876)	(0.899)	(1.407)	(0.895)	(3.451)
LnTO	-1.867	-3.761	-0.128	0.364**	0.000	-0.156**	-0.589**	0.029
	(0.360)	(0.259)	(1.461)	(3.067)	(0.002)	(2.202)	(5.016)	(0.127)
LnEC	5.477		0.886**		1.241**		0.424	
	(0.426)		(11.95)		(3.384)		(1.288)	
LnGDP		0.264		1.109**		0.835**		0.211
		(0.077)		(14.42)		(4.372)		(0.643)
C	-11.484	19.385	1.953**	-2.639**	-0.553	0.817	7.766**	3.877
	(0.293)	(0.238)	(3.322)	(3.743)	(0.233)	(0.583)	(3.555)	(1.180)
Panel C: Diagnostic								
CointEq(-1)	-0.007	-0.074	-0.320**	-0.402**	-0.203**	-0.913**	-0.238**	-0.350**
	(0.370)	(0.277)	(2.553)	(2.739)	(2.695)	(4.740)	(5.179)	(2.407)
Adj-R^2	0.999	0.995	0.998	0.997	0.988	0.967	0.998	0.994
F-statistic	8.451**	2.929	4.202*	1.591	0.815	6.057**	4.918*	3.443
LM	1.223	1.921	1.049	0.062	0.964	2.839*	0.125	0.237
RESET	1.184	0.256	1.002	1.837	3.553*	0.152	1.268	0.152
Hetero	0.414	1.279	0.987	1.287	1.938	0.699	0.974	0.544
CUSUM	S	US	S	S	S	S	S	S
CUSUMQ	S	S	S	S	S	S	S	US

Note: * and ** denote 10% and 5% level of significance, respectively. The values inside the parenthesis are absolute t-ratios. The critical values of RESET and LM tests at the 10% level of significance is 2.70 and at 5% level 3.84.

The short-run and long-run estimates of energy models are also reported for each country in Table 3. The estimates attached to D (ICT) are found to be significant and negative in the case of Bangladesh (0.076%) and India (0.023%) and, positively significant in the case of Sri Lanka (0.037%). Though, the significant effect for Bangladesh was observed at a previous lag. These results imply that Bangladesh and India have achieved energy efficiency due to increased use of ICT hence their energy consumption is on the decline. However, as far Sri Lanka is concerned 1% increase in ICT usage enhanced energy consumption by 0.037% which signifying the fact Sri Lanka is using energy-intensive ICT products which ultimately lead to enhancing energy consumption in Sri Lanka. The coefficient estimates of the D(TO) variable are appeared to be significant at a current lag in Pakistan and Sri Lanka whereas, the estimates are found to be significant one year ago in Bangladesh and India. However, in Bangladesh and Sri Lanka enhanced trading activities have augmented energy consumption with a magnitude of 0.356% and 0.184% respectively. Contrariwise, the opening up of the economy in India and Pakistan has reduced the energy consumption in these two countries, and the size of this reduction is 0.097% in India and 0.142% in Pakistan. As far as the short-run effects of GDP per capita on electricity consumption in South Asian economies are concerned, they are significant and positive for India (0.446%), Pakistan (1.310%) and Sri Lanka (0.838%) and negatively significant in case of Bangladesh (4.086%).

In the long run, the estimates attached to LnICT in our energy models are significant in the case of India and Sri Lanka only. The estimate indicates that a 1% increase in ICT usage in India reduces 0.057% of energy consumption in India inferring that India has achieved energy efficiency by using smarter and energy proficient ICT products. Conversely, in Sri Lanka, a 1% rise in the use of ICT upsurges energy consumption by 0.106%. The impacts of increasing trade activities have a positive influence on energy consumption in India and negative in Pakistan. The magnitude of these effects is 0.364% for India and 0.156% for Pakistan. Lastly, the 1% increase in LnGDP boosts energy consumption in both India and Pakistan by 1.109% and 0.835% respectively. From the estimates attached to LnGDP we can confer that higher per capita GDP in both India and Pakistan has induced the people to buy more energy-intensive appliances like light-emitting diodes (LEDs), air conditioners, electric ovens, refrigerators etc. which will ultimately lead to higher energy consumption. Once again, to prove the legitimacy of our long results we rely on the bounds F-test or ECM_{t-1} test. From Panel C, of Table 3, we can confirm that long results for all countries, except Bangladesh, are cointegrated according to the estimates of one or the cointegration test. Hence, in the case of Bangladesh, our long-run results are not valid.

In Panel C, we have reported the estimates of other diagnostic checks that will further confirm the validity of our results. These diagnostic tests comprise the test of first-order correlation i.e. Langrage Multiplier (LM), the test of misspecification i.e. Ramsey RESET, and test of heteroscedasticity i.e. Breusch-Pagan-Godfrey. The estimates of these diagnostic tests with regard to most of our growth and energy models are insignificant confirming the fact that estimates of our models are reliable. Finally, the parametric stability of our models is also confirmed by CUSUM and $CUSUM^2$. The stability of parameters is represented by 'S' and instability is symbolized by 'US'.

5. Conclusion and policy implications

The role of ICT in economic growth and energy consumption of developed economies is widely established but the literature regarding developing economies is still at the early stage. Therefore, the main objective of the study is to examine the impact of the ICT on GDP per capita and electricity consumption in selected South Asian economies i.e. Bangladesh, India, Pakistan, and Sri Lanka. We have selected these economies as the data on mobile cellular subscriptions which is used as a proxy of ICT is only available for these countries in the South Asian region. In the case of India, Pakistan and Sri Lanka data start from 1990 and for Bangladesh, the series starts from 1992 however, the ending year remains the same i.e. 2018. Two separate models have been constructed, one is known as the model of economic growth with GDP per capita as a dependent variable while, other is known as energy model which considered electricity consumption kWh per capita as a left-hand-side variable. However, in both the models the ICT variable is added on the right-hand side of the equations.

For empirical analysis, we have relied upon the ARDL bound testing approach, and from the results of bounds, F-test and ECM_{t-1} cointegration is confirmed in all economic growth models while in energy models cointegration is confirmed in all countries except Bangladesh. From the estimates of economic growth models positive and significant short-run effects of ICT are only observed in the case of Bangladesh and India, and in rest of the countries, ICT did not show any significant short-run effects on the economic activity. Once again, in long-run, ICT has only shown positive and significant effects on the economic growth of India only. On the other side, ICT help in reducing the energy consumption in India both in short as well as long-run which means that increased use of ICT supports India in achieving energy efficiency. Conversely, as the use of ICT in Sri Lanka increased it augments energy consumption in Sri Lanka both in short-run and long- run. In the case of Bangladesh, ICT negatively and significantly affect energy consumption in short-run while in long-run the role of ICT is insignificant. However, energy consumption in Pakistan is not affected by the use of ICT either in short-run or in long-run. The findings of both the models confirm that the contribution of ICT in economic growth and energy sector of developing economies is still at an early stage. However, in India, the use of ICT has started to show some fruitful effects on the economic growth of India. Moreover, the Indian energy sector has also started to gain energy efficiency through the improved role of ICT in the Indian economy which ultimately will reduce CO_2 emissions in India as the energy attained from non-renewable sources is causing damage to environmental quality worldwide.

Few other important findings are observed during our analysis. In our economic growth model, energy consumption proved to be an important determinant of nations' economic performance. In short-run energy consumption positively contributed to the economic growth of Bangladesh, India and Pakistan however, these short-run effects transmit into long-run in case of India and Pakistan only. Similarly, in the energy consumption model, in the short-run, as the per capita income in India, Pakistan and Sri Lanka increase their reliance on energy consumption also increase. However, the short-run effects of per capita income lower energy consumption in Bangladesh. Once again, just like growth models, the short-run effects in our energy models last into the long-run in the case of India and Pakistan. From these results, we can confer that as the GDP per capita in Pakistan and India increase the people in India and Pakistan will use more energy-intensive products.

From these findings, we can also draw some important policy implications. First of all, ICT does not play any significant role in boosting economic growth or gaining energy efficiency in South Asian economies except India. Hence, following the footprints of India the policymakers in South Asia should focus on ICT driven economic growth policy that would not only boost economic activity but also help to achieve energy efficiency in South Asian economies. Energy-efficient ICT products on one side lower energy consumption but, on the other side also reduce CO_2 emissions because of low energy consumption (Inani and Tripathi, 2017). The long-run positive relationship between energy consumption and economic growth in both India and Pakistan infers that both India and Pakistan rely on energy consumption for their economic growth. Hence, both the country can't adopt the policy of energy conversation as it may negatively affect their economic growth instead they should try to produce more energy through renewable sources and try to achieve energy efficiency (Hamdi et al., 2014; Salahuddin and Alam, 2015).

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Highlights

- We analyze the effects of ICT on economic performance and energy consumption of selected South Asian economies.
- In the long-run, ICT significantly and positively contributed to the economic growth of India only.
- India is the only country in South Asia that has achieved energy efficiency as a result of increased use of ICT.
- GDP per capita has a positive and significant impact on energy consumption in both Pakistan and India.
- South Asian economies try to follow their regional partner, India.