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The Role of Information and Communication Technologies (ICT) in Environmental Quality: An Empirical Analysis for South Asian Economies

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Abstract: Present study is an attempt to provide an in-depth understanding of the relationship between ICT, financial development, governance effectiveness, and COE nexus in selected South Asian countries. The data were acquired from WDI and applied FMOLS, DOLS, FEOLS methods of estimation for the period 1995-2019. It is observed that ICT has negative while financial development has a positive impact on COE in the case of four South Asian economies. Concerning the impact of governance on COE, it is observed that governance effectiveness is negatively associated with COE. It is evident from the empirical analysis that COE can be mitigated with effective governance policies.

Keywords: ICT, environmental quality, empirical analysis, south asia, economy.

Introduction

In the recent decade, information and communication technologies (ICT) are ruling the world. The use of cell phones, particularly, has become an essential part of everyday life. Besides, ICT helps to boost many other sectors in the economy; for example, use of the internet reduces transaction costs in the financial sector, increases investment activities in the economy, and uplifts the trade sector (Ahmed and Ridzuan, 2013). The use of the internet also makes it possible for firms to utilize new and advanced technologies. Though, the use of ICT is acting as a double-edged sword. On one hand, it is connecting people and businesses around the globe while on the other hand, it is enhancing the level of industrialization in the economy (Higón et al.,2017). Rapid industrialization is a crucial factor to increase energy consumption and degrading the environment. However, the role of ICT cannot be undermined to control the environmental pollution (Asongu et al., 2019). It can help to find advanced and efficient ways to use energy. The use of ICT increases the possibility to find new channels to reduce environmental pollution and invest in new and cleaner technologies. The use of ICT, particularly the use of the internet can decrease environmental degradation (Lange et al.,2020) and the workers can stay at home. The recent example of COVID – 19 is valid in this regard. During the lockdown, the use of ICT helped many workers to work from home. This way they retained their jobs. Work from home model also decreases the transaction costs and saves the fuel costs for the workers and the economy in terms of environmental pollution (Cerqueira et al., 2020).

ICT connects individuals, businesses as well as economy. It also helps to integrate economy and enhances productivity. Immense literature is found on the positive role of ICT in economic growth, for example, Gruber and Verboven, (2001); Meng and Li, (2002); Carayannis and Popescu, (2005) and Appiah-Otoo and Song, (2021). ICT facilitates market competition as well as foreign and domestic investment. In many studies, the advancement in ICT is considered a triggering factor for rapid globalization and economic integration. However, on tcontrary, Wang, (1999); Kenny, (2003), and Shiu and Lam, (2008) found a negative impact of ICT on economic growth. Besides, Lee et al., (2005) also indicated that ICT is not contributing to the growth process positively in developing countries. To sum up; ICT is playing a pivotal role in the economic growth process, however, it is not possible to ignore its effect on environmental quality.

The recent strand of literature elaborated ICT as a significant factor behind CO_2 emissions (COE hereafter). The development of ICT infrastructure and the use of different ICT tools and equipments enhance economic growth but at the same time, it can increase COE. However, the literature found mixed shreds of evidence to find out about the role of ICT concerning COE. Most of the previous studies are of the view that the use of ICT can decrease COE by finding out different ways to use energy efficiently, reducing transportation costs by staying and working from home, and providing information about cleaner technology options through research and development (Haini, 2021). Batool et al., (2019) revealed that ICT exerts a negative influence on environmental degradation for South Korea during the period 1973–2016. In another interesting study, Ozcan and Apergis, (2018) are of the view that ICT is helping to decrease environmental degradation for emerging economies. Though, few other studies indicate that investment in ICT structure is enhancing the COE since the development of ICT infrastructure requires intensive energy consumption. In this regard, the most important

studies have been conducted by Balsalobre-Lorente et al., (2019) and Haseeb et al., (2019). Lu, (2018) also found the positive impact of ICT infrastructure on environmental degradation. Besides, Salahuddin et al., (2016) confirmed the negative association between ICT infrastructure and COE. Higon et al., (2017) found a nonlinear relationship between ICT and COE for groups of developed as well as developing countries. Further, for the panel of G7 economies, Raheem et al., (2019) revealed that ICT is a leading factor to improve quality of environment. In the same vein, Arshad et al., (2020) also found a favourable link between these two variables.

Theoretically, financial development (FD) exerts an influence on COE owing to three effects. First, the income effect, in which per capita income increases due to FD, and people can buy more energy-intensive goods or vice versa. Secondly, scale effect that is related to the increase in production. During the production process, if FD paves the way towards energy-intensive technologies then it brings an increase in COE. On the other hand, if FD promotes environmental-friendly technologies then COE decreases. Third is the capitalization effect which is related to the investment. Thus, if FD promotes investment in environmentally friendly sectors then it helps to promote environmental quality and vice versa (Yuxiang and Chen, 2011). The existing literature on FD and COE is also inconclusive so far. On the one hand, a favourable impact of FD is found on COE (Shahbaz et al., 2013; Khan and Ozturk,2021), while, FD is also impeding environmental quality (Khoshnevis and Ghorchi Beygi, 2018; Jian et al., 2019). In simple words, FD is insignificantly associated with COE (Bayar and Maxim, 2020).

In the recent era, institutional failure and poor governance are considered the most prominent reasons for many environmental problems (Asongu and Odhiambo, 2020). Therefore, countries with effective governance policies tend to manage their environment better. Generally, environmental policies have better chances of implementation in presence of effective governance policies (Muhammad and Long, 2021). Literature also highlights that environmental degradation often stems from institutional failures. Danish and Wang, (2019) for BRICS economies, inferred that governance effectiveness promotes environmental quality. Similar conclusions were drawn for high CO_2-producing economies by Lie et al., (2020). Asongu and Odhiambo, (2020) took a sample of the Sub Saharan economies and concluded that effective governance modulates COE.

The previous literature provides evidence of the positive influence of gross domestic product (GDP) on COE. The higher growth rate in economy paves the way towards macroeconomic stability. Since it increases employment opportunities, so a high standard of living is brought in turn. Higher per capita incomes, lower budget deficit, and rapid human capital accumulation. However, in most cases, economies have to face a trade-off in terms of environmental quality when they are achieving high and stable growth rates. An extensive body of literature is supporting a positive influence of GDP on COE for instance: Tiwari, (2011); Farhani and Ben Rejeb, (2015); Mitić et al., (2017); Ameyaw and Yao, (2018); Gong et al., (2019); Munir et al., (2020).

Based upon these arguments, the present study will assess the role of ICT, financial development, governance effectiveness, and GDP on COE in case of selected South Asian economies. The study intends to address four specific research questions. 1) Does ICT play a pivotal role to upsurge COE in the selected panel of economies or vice versa? 2) Does financial development increase or decrease COE? 3) Does the governance effectiveness increase or decrease COE? 4) Does GDP increase or decrease COE? To assess the validity of these research questions the study applies the most appropriate and advanced econometrics techniques.

After carefully examining the existing literature, the present study is focusing on the ICT-COE nexus for the South Asian economies. The study will provide new insight to the academic discussion on the ICT-COE nexus in many ways. It has utilized the latest available data for empirical analysis. In addition, it has included the most important economies in the South Asian region with geographic importance.. It has applied the most advanced econometrics techniques to explore the mentioned linkage. The study also provides policy insight for the policy practitioners which can be utilized for other developing economies.

Material and Methods

Table 1 described the description of the included variables in the present analysis for the period 1996 to 2019. The South Asian countries included are Pakistan, India, Sri Lanka, and Bangladesh. The data is extracted from World Development Indicators, the official data of the World Bank.

Table 1 Description of the selected variables.

Variable	Symbol	Definition
Corban emissions	COE	Carbon dioxide emissions (kilotons).
Information and communication technologies	ICT	The number of internet and mobile users.
Financial Development	FD	Domestic credit by the private sector percentage of GDP
Governance effectiveness	GE	The quality of governance, including the quality of public services.
Gross domestic product	GDP	Real GDP.

Source: World Development Indicators

The prime objective of the study is to explore the ICT-COE nexus for selected South Asian economies. After having a look at the diverse literature on the significant

factors which are associated with COE, the present study have identified and included the most important variables in the empirical analysis; for example, ICT, FD, GE, and GDP (Munir et al., 2020; Asongu and Odhiambo, 2020; Khan and Ozturk,2021; Khan and Ozturk,2021). However, in a particular context, the present study has followed Godil et al., (2020) to construct the econometric model. It is expected that ICT can exert a favourable or unfavourable influence on COE. The same is true for FD and GDP. However, as per most of the previous studies, governance effectiveness improves environmental quality. The general form of the model is:

$$COE = f(ICT, FD, GE, GDP) \quad (1)$$

By transforming equation 1 into a natural logarithm function the model will take the following form.

$$\ln COE_{it} = \alpha_0 + \alpha_1 \ln ICT_{it} + \alpha_2 FD_{it} + \alpha_3 \ln GE_{it} + \alpha_4 \ln GDP_{it} + \varepsilon_{it} \quad (2)$$

In the next step, to find out the stationarity of the selected variables, the study has applied panel unit root tests.

Table 2 Panel Unit Root Tests.

Variables		Intercept		Trend & Intercept	
		Stat	Prob	Stat	Prob
First difference					
COE	LLC	-3.862	0.000	-4.131	0.003
	IPS	-4.223	0.000	-3.960	0.002
ICT	LLC	-3.772	0.000	-3.932	0.053
	IPS	-4.243	0.000	-5.781	0.002
FD	LLC	-4.123	0.000	-6.311	0.000
	IPS	-7.561	0.000	-5.871	0.001
GE	LLC	-5.466	0.000	-4.421	0.000
	IPS	-4.952	0.000	-2.771	0.000
GDP	LLC	-4.978	0.000	-5.650	0.001
	IPS	-3.021	0.000	-3.64	0.003

The panel unit root test reveals the order of the integration as well as the stationarity of the selected variables. By using LLC and IPS tests, the revealed order of integration is 1 for all the selected variables. Therefore, it is indicated that variables will have a long-run association. There are many techniques in the literature to find out the long-run association between different variables. However, keeping in mind the order of integration I, the present study applies two techniques namely, fully modified ordinary least square (FOLS) and dynamic OLS (DOLS). The FMOLS was used by Pedroni to solve the problem of endogeneity and also the serial correlation between the regressors. The DOLS method was proposed by Stock and Watson (1993) and later it was extended by Kao (1999). The DOLS method is also helpful to correct the problem of endogeneity. For the comparison of the empirical results, the study used fixed-effect OLS (FEOLS).

Results and Discussion

Table 3 Descriptive statistics.

Variables	COE	ICT	FD	GE	GDP
Mean	2.511	5.077	10.861	0.616	10.776
Maximum	4.021	6.091	13.143	1.283	12.441
Minimum	1.412	2.001	8.096	0.088	9.551
Std. dev.	0.699	0.466	0.851	0.321	0.708
JB	6.021	5.261	7.312	5.977	5.321
Prob	0.001	0.020	0.000	0.000	0.006

Table 3 presents the descriptive statistics of the selected variables. The mean value of COE is 2.511, and the mean value of the variable ICT is 5.077. Moreover, the mean value of governance effectiveness is 0.616, the mean value of financial development is 10.861 and the mean value of GDP is 10.776.

Table 4 Pedroni Cointegration Test.

Common AR coefs. within dimension				
	Stat.	Prob.	Weight. Stat.	Prob.
V-statistics	9.25	0.00	5.23	0.120
Rho-statistics	4.22	0.110	2.11	0.206
PP-statistics	-3.10	0.001	-4.11	0.001
ADF-statistics	-6.12	0.001	5.00	0.000
Individual AR coefs. between-dimension				
Rho-statistics	5.99	0.430		
PP-statistics	3.16	0.000		
ADF-statistics	-8.09	0.000		
Kao`s cointegration test				
	t-stats	Prob		
ADF	-4.231	0.000		

Since the variables are integrated of order I, then it is preferable to apply at least one cointegration test to confirm the existence of long-run relationships among the selected variables. The study used two-panel cointegration tests namely: Pedroni panel co-integration test (Pedroni, 1999; 2004) and the Kao panel co-integration test (Kao, 1999). The reported results in Table 4 confirmed the existence of cointegration among selected variables at 1 per cent.

Table 5 Panel Long Run estimators.

Variables	FMOLS	DOLS	FE OLS
ICT	-0.311** (0.020)	-0.021*** (0.000)	-0.011** (0.000)
FD	0.190*** (0.00)	0.151** (0.030)	0.181** (0.040)
GE	-0.312*** (0.000)	-0.051** (0.041)	-0.29** (0.020)
GDP	0.110*** (0.00)	0.210*** (0.001)	0.521** (0.040)

***, **, * represent 1, 5 & 10 percent level of significance. In parenthesis ( ) are probabilities.

In Table 5, the results of the estimations are expressing the value of each coefficient and its probability values. Here, the dependent variable is COE. In model 1, the coefficient value of ICT shows that if ICT increases by

one per cent then the COE will decrease by 0.311% for the selected countries in the South Asian block. The result is found consistent with Batool et al. (2019), and not consistent with and Haseeb et al., (2019). Raheem et al., (2019) expressed the same relationship for a panel of G7 economies and inferred that ICT is exerting a positive influence on COE. On the contrary, Godil et al. (2020), assessed the ICT-COE nexus for Pakistan. By using QARDL, the study explained that ICT decreases COE in Pakistan. However, in contrast to empirical results presented in this study, Arshad et al., (2020) also elaborated a positive association between ICT and COE for South and Southeast Asian regions. Further, in the case of the Iranian economy, Shabani and Shahnazi, (2018) also supported a favourable impact of ICT on environmental quality.

The coefficient of governance effectiveness is showing a negative relationship with COE, therefore, it is concluded that governance effectiveness is negatively associated with COE in the selected South Asian countries. The empirical results are supported by various studies from the literature on governance and COE nexus for different countries around the globe (Halkos and Tzeremes, 2013; Halkos et al.,2013; Yang et al., 2018; Haseeb et al., 2018; Asongu and Odhiambo, 2020). The empirical results are also consistent with Baloch et al. (2019). As the study explored the governance-COE nexus for BRICS economies and inferred that effective governance is a strong pillar to improve environmental quality. Similarly, in another interesting study, Liu et al., (2020) also highlighted the impact of effective governance on COE for the top five CO_2 emitters' economies. The study inferred that effective governance is one of the essential contributing factors to improve environmental quality. In the same context, Abid, (2016) also expressed the favourable influence of effective governance on environmental quality in the Sub-Saharan African region.

The coefficient of the financial development shows that if FD increases by one percent then COE will increase by 0.190%. The result is found similar to Shahbaz et al., (2013); Pata,(2018); Ahmad et al., (2018), and Shoaib et al.,(2020). An extensive body of literature is supporting the unfavourable impact of FD on environmental quality. There are three channels through which FD upsurges COE, including scale effect, capitalization effect, and income effect channel (Yuxiang and Chen, 2011). Khan et al., (2020) highlighted that FD is acting as a detrimental factor to environmental quality. On the same lines, Abbasi and Riaz, (2016) also assessed the unfavourable impact of the FD on COE in case of the Pakistani economy. However, Khan et al. (2018) expressed that FD is playing a positive role in decreasing COE.

The coefficient of the GDP shows that if GDP increases by one per cent then COE will increase by 0.110%. The empirical results are supported by the previous and recent literature; for example, Magazzino, (2016); Bekhet and Othman, (2018); Magazzino and Cerulli, (2019); Balli et al., (2019); Beşe and Kalayci, (2019) and Munir et al., (2020). Further, Mitić et al., (2017) took the case of transition economies and supported a positive interconnection between GDP and COE. Jian et al., (2019) also express GDP as a detrimental factor of COE in China. Further, Munir et al., (2020) also supported that GDP is impeding the environmental quality in ASEAN economies.

Almost similar results are found for the other two models, i.e DOLS and FEOLS. The empirical estimates obtained from these models also support this notion that the use of ICT and effective governance policies help to reduce COE in selected South Asia countries.

Summary and Conclusion

The present study illustrates the role of ICT in environmental degradation in selected South Asian countries. This study contributes in understanding the ICT and COE nexus in South Asian countries. Following the results, it is found that ICT exerts a significant and negative impact on COE whereas, governance quality is also negatively associated with COE. The study also included financial development and concluded that there is a positive and significant association between FD and COE. Moreover, COE is also significantly associated with GDP. The study provides useful policy insights for the policy practitioners in South Asian economies. It is important to encourage the use of ICT in these economies to mitigate COE. It is also important to focus on effective governance policies to improve the environmental quality in these economies. Due to data limitations, the study included the number of internet and mobile users in this study. However, in the future, depending upon the data availability, researchers may add different proxies of ICT. Further, the researchers can also explore the ICT-COE linkage for other economies.

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