Role of Information and Communication Technology, Foreign Direct Investment and Trade Openness in Environmental Sustainability

Sulaman Hafeez Siddiqui, Institute of Business Management and Administrative Sciences, The Islamia University of Bahawalpur, Pakistan.

***Sohail Saeed**, Institute of Business Management and Administrative Sciences, The Islamia University of Bahawalpur, Pakistan

Areeba Khan, Institute of Business Management and Administrative Sciences, The Islamia University of Bahawalpur, Pakistan

Hina Bhatti, The Islamia University of Bahawalpur, Pakistan

*Corresponding author's email: sohail.saeed@iub.edu.pk

ARTICLE DETAILS

History

Revised format: Mar 2021

Available Online: Apr 2021

Keywords

Information and Communication

Technologies (ICTs),

Environmental

Sustainability, International

Trade and Investment

JEL Classification

Q56, F18, F21

ABSTRACT

Purpose: The benefits of Information and Communication Technologies (ICTs) in environmental resource management has been a topic of hot discussion for the policymakers across the world. For the purpose, the government of Pakistan took initiative in 2018 to use technology for the country's social welfare, financial benefits and to enhance environmental sustainability and named it as "Digital Pakistan Initiative".

Design/Methodology/Approach: For analysis, this study took CO2 emissions as the dependent variable and ICT, FDI inflows, and Trade Openness as independent variables. Data were collected on bimonthly basis from 2004 through 2019, and analyzed employing ARDL approach.

Findings: The findings show that there exists a short-run relationship among all the variables; however, FDI inflows and trade openness have a significant relationship with CO2 emissions. The results also exhibit that there is no long-run relationship between CO2 emissions, FDI inflows, and Trade openness while ICT has an insignificant long-run relationship with CO2 emissions. With the increase of information and communication, the country's environmental sustainability is also increased.

Implications/Originality/Value: The current study was based on least considered variables and the pioneer in testing the complex relationship through VAR estimation.

©2021, The authors, under a Creative Commons Attribution-NonCommercial 4.0

Recommended citation: Siddiqui, S. H., Saeed, S., Khan, A., & Bhatti, H. (2021). Role of Information and Communication Technology, Foreign Direct Investment and Trade Openness in Environmental Sustainability. *Journal of Accounting and Finance in Emerging Economies*, 7(2), 271-280. <https://doi.org/10.26710/jafee.v7i2.1656>

1. Introduction

The rapid growth of the development of society in current years has been improved with the continuous development in the extent of information and communication technologies (ICT). Its approval by the nation, community establishments, and the creativities in all spheres of life is growing as healthy as the aggregate role of information (Frankel & Romer, 1999).

In Pakistan, the CO₂_EMS from the combustion of fuel was recorded as 183.4 million tons (IEA, 2019). Societies that are good at using ICT to efficiently produce, spread, and use information will achieve social and economic benefits, hit the competitive market's edge, and develop improved welfare opportunities for their people (Nizam et al., 2020). Over the past fifty years, developed and more refined concepts of information are developed by researchers in different aspects such as economic, political, technical, and social (Ziemba, 2019).

At the same time, in many countries, the development of information is a priority. In addition to sustainable development, information technologies are helpful in growth, human advancement, and well-being. Some studies show that countries with high levels of progress in the knowledge-based society are countries with high levels of economic and social growth (Ireland & Clausen, 2019).

In the Information and Communication Technology (ICT) market, environmental concerns such as global warming, energy use, and e-waste are pushing the idea of green computing into the spotlight. As a result, many organizations are embracing cloud-based services and virtualization that include a common pool of remote computing tools, all of which contribute to supporting Green ICT. Major companies such as Microsoft, for example, estimate that cloud-based operations would allow organizations to reduce their carbon footprint by 30% to 90% (Whitepaper, 2014).

The toxic elements used to make the LCD and displays for PCs and laptops are Rare Earth Elements (REE). The use of these REEs, however, is not solely responsible for ICT carbon emissions, but there are simultaneous effects on the extraction and disposal process, which consumes a lot of non-renewable resources. Carbon emissions from the ICT industry have, however, been on a downward trend from 2012 to 2015. In 2012, Carbon emission decreased by 0.7%. Globalization brings liberalization of the economy that raises market competitiveness and prices, thereby improving the economic scale. These factors are guiding the globalization of the ICT sector (Rohman, 2013).

Carbon emissions ensure crack out to be a threat towards the sustainability of the biosphere environment. Using the growth in the practice of motors and different equipment, the procedure of fossil fuel and further biological gasoline ends in the exponential growth of carbon emission addicted to surroundings (Patterson et al., 2019). Without supervisory high emissions and severe weather adjustments, it is difficult to attain sustainable enlargement (Cetin et al., 2010). The role played through ICT within the improvement of clever and sustainable capitals internationally cannot be over-emphasized (Nizam et al., 2020). The users maybe not ready to accept the technology which also affects IT performance. Due to this unwillingness, the economic growth is suffered (Hafeez et al., 2018).

The vital aim of this study is to check the effect of ICTs penetration on carbon emissions along with other factors as trade openness and FDI inflows and energy demand. The studies of previous literature are indecisive and there is a need to reinvestigate it by using sophisticated and latest modeling bounds testing procedure techniques.

2. Literature Review

Furthermore, ICT is the connecting component of manageability's triple-helix measurement: economy, atmosphere, and society. Some examinations have discovered that web use, an intermediary for ICT, builds carbon outflows in the BRICS setting. Comparable discoveries have

been gotten by contemplates zeroing in on the Asian zone, consequently negatively affecting ecological quality (Balsalobre-Lorente et al., 2019).

Asongu (2018) found that ICT can be utilized to reduce globalization's conceivably unsafe effect on ecological corruption (Asongu et al., 2019). For a board of 20 developing economies during the period, 1990 to 2015, Ozcan and Apergis (2017) found that web network, an intermediary of ICT, added to diminishing air pollution (Ozcan & Apergis, 2018).

Kreith et al. (1990) found that all out-carbon emanations originate from four unique kinds of intensity plants, i.e., US gas, sun-based warm, and photovoltaic force plants. The examination details that by exchanging vitality sources from petroleum derivatives to sustainable power sources that will help the supportability plan of the nation. As the powerful usage of the ICT system is significant for the comprehensive, fair, and manageable financial development of Europe, the EU plays a main part in supporting the mission for an advanced plan for Europe (Gouvea et al., 2018). ICT's part in the worldwide production of savvy and manageable urban areas cannot be overstressed (Cetin et al., 2010). By utilizing the STIRPAT model, Zhang and Liu (2015) explored the connections among data and correspondence innovation (ICT) and carbon dioxide emanations in China at public and provincial levels over the period 2000-2010. They found that the ICT business has a possible task to carry out in diminishing carbon dioxide discharges.

Ozcan and Apergis (2017) analyzed the impact of ICT on CO₂ outflows over the 1990-2015 period in 20 rising economies. Web clients have been utilized to figure ICT and have demonstrated that more significant levels of web users have added to the decrease of air contamination. Moreover, it is demonstrated that ICT had no critical impact on the discharge of carbon dioxide, while by utilizing the intuitive word, ICT significantly affected CO₂ emissions (Asongu et al., 2019). Geng et al. (2011) reasoned that coal-based vitality frameworks greatly affect China's carbon emanations; thus, up-gradation of innovation would help limit carbon outflows.

During the period 1980-2012, Zoundi (2017) contemplated the vitality outflows nexus in a board of 25 African nations and found the positive connection between carbon emanations and per capita pay, while sustainable power source has a negative relationship (positive effect) on carbon discharges that are viewed as an ideal trade for fossil fuels. Putting resources into cutting edge monetary segment, ICT advancements mitigates vitality utilization yet besides increments natural quality by low CO outflows (Latif et al., 2018).

Through the utilization of Pedroni board co-reconciliation and pooled mean gathering assessor procedures, Salahuddin et al. (2016) found the impact of financial development and web use on discharges in OECD nations for the period 1991–2012. They uncovered that all the elements are co-coordinated. Sims et al. (2003) contrasted the expense of intensity creation and expected sources and innovation through existing business advances. The discoveries show that most advancements, except for sunlight-based force and carbon dioxide sequestration, can limit creation expenses and decline carbon discharges.

The connection between vitality utilization and CO₂ outflows has been explored in numerous investigations. Vitality is one of the principal improvement factors and is viewed as the main impetus for monetary development and advancement. Sahir and Qureshi, (2007) reasoned that there was an away between complete utilization of essential oil, outflows of CO₂, and financial development. It has likewise been examined that both the general utilization of essential vitality has a positive causal relationship with financial development and other monetary viewpoints assume a significant function in accomplishing high financial yield because of higher contamination. Vitality utilization is brought about by globalization and by financial growth (Saud et al., 2018).

For the period from 1960 to 2004, Soytaş et al. (2007) examined the granger causality connection of the vitality pay outflows nexus in the feeling of the US economy. The discoveries demonstrate that vitality creation doesn't cause long-haul carbon discharges yet impacts vitality utilization; in this manner, it is sensibly gathered that vitality request is less defenseless to ecological pollution. (Soytaş et al., 2007) The discoveries indicated that Granger's carbon emanations add to vitality utilization, yet they don't appear to work backward. The discoveries propose that the Turkish economy should organize practical advancement strategies to diminish carbon emissions (Soytaş and Sari, 2009). For the period from 1985 to 2006, Dhakal (2009) investigated the vitality outflow nexus in China. The outcomes show that 84 percent of China's vitality use is monetarily contributed by metropolitan regions of the nation, of which more than 40% is utilized by only 18 percent of the populace living in little towns (Dhakal, 2009).

Coroama and Hilty (2009) analyzed the worldwide collaboration among innovation and vitality and found that ICT can possibly limit vitality utilization through low vitality utilization and low vitality sparing potential for innovation (Coroama and Hilty, 2009).

Ishida (2015) analyzed Japan's long-haul vitality innovation salary connection somewhere in the range of 1980 and 2010 and presumed that ICT venture could add to lessening vitality utilization by advancing development in green advances in a region (Ishida, 2015).

The vitality discharge nexus relationship in the vehicle division was concentrated by Wang et al. (2017). The general impacts of improved eco-friendliness of vehicles are analyzed, guaranteeing further utilization of electric vehicles and more expenses on carbon outflows and non-renewable energy sources. In this report, the Chinese economy is seen as a contextual investigation. The discoveries recommend that the vehicle segment's vitality utilization would ascend to 636 million tons in 2050, bringing about a noteworthy increment in carbon emanations of 1602 million tons in 2050. The examination inferred that the Chinese government should expand vehicle eco-friendliness, support specialized framework and widen the electric vehicle market, all of which would contribute successfully to diminishing vitality utilization and carbon emissions (Wang et al., 2017).

At present, because of the ascent in ecological debasement because of the amassing of human ozone harming substances, for example, carbon dioxide, methane, and nitrous oxide, there is a significant risk to the world's environment. Moreover, unfamiliar direct venture (FDI) and financial advancement have been viewed as the key factors that may add to this result. Accordingly, in contrast to belief systems, by its effect on nature, FDI may effectively affect welfare (Abdouli and Hammami, 2017).

Pickavet et al. (2008) investigated the possible impact of ICT on the manageability of nature and vitality, explicitly worldwide power. The discoveries show that all-out server farms utilize worldwide will ascend later on to 12 percent for every annum. In any case, owing to a great extent to LCD exchanging shows, the force use of PCs is diminished to 7.5 percent per annum. From 2008 to 2020, ICT's vitality utilization rose from 168 to 430 GW. It might be accepted that ICT brings down complete vitality utilization, yet vitality utilization has still ascended from 8 to 14 percent for each annum internationally. In the coming years, accordingly, ICT assets should be more successful to impact the world's complete force consumption (Pickavet et al., 2008).

3. Research Methodology

It is commonly recognized that panel unit root tests are more influential as associated with the time series test. In time series, the unit root test is a causal trend. Having unit root in some sequences, it displayed unexpected specific patterns. In a time-series data unit root test is used to find the

stationary. In spreading's shape, the data is stationary when the variables in the time series do not make any changes.

For testing the process of unit root the study used the ADF unit root test at "constant" and "constant with drift" (Nizam et al., 2020) In econometrics literature with applied time sequences the unit root test is standard training (Ahmed & Ahmed, 2018).

The bounds testing approach exists a co-integration procedure established to check the long-term connection concerning variables in a model. This method displays additional stable outcomes uniform in a slight section (Pesaran et al., 2001).

By using the ARDL procedure, Salahuddin et al. (2016) found that economic growth and internet usage have positively affected electricity consumption in the long run and have an insignificant relationship when checking in the short run as well as for the long run for the countries of OECD.

4. Analysis and discussion

In the first section which is the most important to analyses is that individual time series are stationary on the first point of equal or at main difference So, for this purpose we have to apply the co-integration test because we have to identify this in order of co-integration. For this purpose, AIC Augmented Dickey-Fuller have been applied for checking data stationary. So, we state the unit root equation as follow;

Eq. 4.1

$$\Delta Y_t = \alpha_0 + \delta_1 Y_{t-1} + \sum_{j=1}^p d_j Y_{t-j} + \varepsilon_t$$

Here Y is the individual time series and t is the time, ΔY shows the change in time series over time. Y_{t-j} Indicates the lag value of a variable, α_0 and δ_1 indicates the estimation coefficient and ε_t is the residual or error term. P specifies the maximum lag length of an individual variable.

Variables	Level	First difference(*)	conclusion	p-value	
CO ₂	-1.59	-4.89	I (0)	0.00*	
FDI	-3.00	-3.87	I (0)	0.00	
ICT	-1.69	-5.51	I (1)	0.00	
TO	-0.54	-3.19	I (0)	0.04*	
	<i>Critical Value</i>				
		CO₂	FDI	ICT	TO
	1%	-4.00	-4.12	-4.88	-4.00
	5%	-3.09	-3.14	-3.82	-3.09
	10%	-2.69	-2.71	-3.36	-2.69

Table 1: Hypotheses Testing

Source: Authors' compilation

In table 1, the variables are stationary at dissimilar levels. Certain are at first variance and certain are at level. These results are taken by using intercept, and those models that we got are always best to fit in containing stationary data at the level and first difference.

CO₂, the dependent variable, is stationary at a level with the lag 0 as its p-value is fewer than 0.05.

In the circumstance of CO₂, we reject the null hypothesis and the absolute value is higher than 5% of the critical value than -3.098596. We have got these significant results with the intercept.

The case of FDI at the first level with lag 2 the p-value is very much accurate as this is 0.0047 which is also less than 0.05. Therefore, we also discard the null hypothesis here which indicates that our model is significant with the variable. The absolute value is greater than the critical assessment at 5% and the data is stationary at the level.

ICT is more significant as we test at 1st difference with the lag 1 when doing the ICT unit root test, we got to know that the absolute value is higher than the 5% of the critical value which means the data is stationary and the p-value is 0.004 less than 0.05 so, we conclude that the data is stationary at 1st difference.

TO is stationary at the 1st difference as the p-value is less than 0.05 which have shown us that the data is significant and we then reject the null hypothesis.

Variables	Lag 1	Lag 2
CO ₂		-4.37*
FDI		2.17*
ICT	3.87*	
TO		6.75*

Table 2: Lag Length Determination

Source: Determinations of lags are by using VAR estimates using SBC and AIC values.

As we can see in the above table the Carbon emission, foreign direct investment inflows and trade openness remain arranged through appropriate lag 2 while the Information communication technologies have lag 1 with the use of VAR estimation. Optimal lag values are listed in the above table. For this purpose, Akaike info criterion (AIC) values have been reported in this table.

Descriptive Statistics of variables

In descriptive statistics, minimum, maximum, mean, standard deviation, skewness, and kurtosis have been discussed. The range of skewness is between ± 1 and the range of kurtosis is between ± 3 .

variables	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
Carbon Emission	0.76	1.05	0.93	0.07	-0.33	2.34
FDI	0.55	3.66	1.68	0.94	0.72	2.62
ICT	1.94	8.69	4.39	2.02	1.07	3.17
TO	2.50	29.04	8.57	7.92	1.77	4.85

Table 3: Descriptive Statistics

Source: Authors' compilation

In above table, the mean value of carbon emission is 0.93 and standard deviation is 0.07. Skewness is -0.33 which is negatively skewed, and kurtosis is 2.34. Similarly, the data of other variables are shown.

Serial Correlation LM tests

This residual test is rummage-sale towards confirming if the variables in the perfect have autocorrelation. In this case, our null hypothesis is that no autocorrelation occurs. If the p-value of the Obs*R-square value is greater than 0.05, this specifies that the null hypothesis should not be discarded, and the Serial Autocorrelation Test result is negligible ($p > 0.05$).

F-statistics	Obs*R-squared	Prob.	Prob. Chi-
2.58	6.37	F (2,7) 0.14	Chi-Square (2) 0.04

Table 4: Breusch-Godfrey Serial Correlation LM Test

Source: Authors' compilation

Results of Serial Correlation LM tests

To check if the variables in the model have autocorrelation, this residual test is used. Our null hypothesis, in this case, is that no autocorrelation exists. If the Obs*R-square value's p-value is greater than 0.05, the null hypothesis cannot be dismissed, and the outcome of the Serial Autocorrelation Test is negligible ($p > 0.05$). The result in the above table indicates that the p-value is 0.04, which is smaller than 0.05, and this means that the data is autocorrelated.

ARDL Model Selection

Now, the co-integration test is proceeding with the use of bounds test for cointegration there is a need to know the long-run relationship among the variables. Therefore, Autoregressive Distributive lag (ARDL) approach is one of the most useful and appropriate approaches in which we have a time-series of combination $I(0)$ and $I(1)$. ARDL procedures long run consistent estimation, and practically can use for the small samples. Once when we have done with the investigation and confirm the long-run relationship we also apply ECM Error Correction Model for the short-run fluctuation of the variables and the restoration of the short-term shocks to long-run equilibrium.

Variable	Coefficient	Std. Error	t-statistics	Prob.
D(FDI)	0.03	0.00	4.79	0.00
D(ICT)	-0.01	0.00	-3.76	0.00
D(TO)	-0.00	0.00	3.46	0.00
CointEq (-1)	-0.03	0.09	-3.69	0.00

Table 5: ECM Table

Source: Authors' compilation

Results of ECM

The value of the CointEq (-1) is the value of ECM. This is the error correction model coefficient which range must be from 0-1. If the value of any variable is with a negative sign it means that the dependent variable is converged towards equilibrium and the equilibrium is correct, and if the values of the variables are in the positive sign which means there is divergence and the model is going toward disequilibrium. In our case, the value is -0.35 which we can say -35.5%. The value is in a negative sign so we can say that the dependent variable converges towards equilibrium. Every year our dependent variable carbon emission converges towards equilibrium. The important part of the result is that the value of ECM is negatively significant that is CointEq-0.35. In some cases we call it as adjustment terms or the adjustment coefficient and it must be negative in order to get the long-term equilibrium. If this value is positive, it means that our model exhibit explosion.

Test statistics	Value	Significance	I (0) Bound	I (1) Bound
F-statistics	0.84			
K	3			

	10%	2.72	3.77
	5%	3.23	4.35
	2.5%	3.69	4.89
	1%	4.29	5.61

Table 6: ARDL Bounds Test

Source: Authors' compilation

Long-run Equilibrium Relation

We are now continuing from here to test for co-integration by using the co-integration-related test. In fact, we do this to discover whether there is a long-term relationship among these factors. For performing bound checks, we use coefficient diagnostics in EVIEWS. We readily interpret the long-run relationship after confirming the short-run outcome. For all the variables with carbon emission (CO₂) inflow, our findings are very important.

From our results of the ARDL Bounds test, The Value of F-statistics is 0.84 at the 5% of significance level where I(1) is the upper value and I(0) is the lower value. The value of I(0) bond value is 3.23 while the I(1) bond value is 4.35.

So, if the value of F-statistics is above than I(1) we can say that there exists a long-run relationship. If the value of lower bond I(0) is higher than F-statistics then we can say that there is no long-run relationship. So, in the case of foreign direct investment inflows, there is no long-run relationship with carbon emissions. However, there is a long-run relationship between information and communication technologies and the trade openness because the values of these two variables are below 0.5.

These are the findings of the ARDL Long-Run Bounds Test results. In the table above, I(1) shows the upper boundary level, while I(0) shows the lower level, and most of the 5% of the values are verified. The primary subject of attention is the Bound Test F-statistics.

The null hypothesis shows that there is “there is no long-run relationship exists” but the null hypothesis is not valid at all in our actual data, because there is a long-run relationship between the variables. The rejection criteria here clarify that if the value of F-statistics is higher than the I(1) bound statistics, we reject the null hypothesis. If the F-statistics value is less than the I(0) bound value, the null hypothesis cannot be dismissed. If the F-stat value is bound between I(1) and I(0), it means that the outcome is inconclusive and we will start our study all over again. Our status is greater than the I(1) bound in favor of the alternative, an indicator that we have to reject the null hypothesis. We, therefore, assume that there is a long-run relationship between the variables in this model since we can see from the above table that the F-statistic value is 0.8, which is lower at a 5 % level than the value of I(1). But with these outcomes, we are good.

4. Conclusion

The observed empirical finding shows that information and communication technologies along with FDI inflows and trade openness have significant effect on Carbon emission in Pakistan. Carbon emissions have optimistic effect on FDI inflow in the short-run as our test shows from the Table that if Carbon emissions increases by 1% then FDI inflow in Pakistan increases by 0.02%, similarly the information and communication technologies (ICT) decreased -0.04% in the long-run relationship with carbon emissions CO₂ as increase by 1 %. The Trade openness is increased by 0.00% as the Carbon emission CO₂ increase by 1%. We also see the T-statistics values from the table to find out the significance level of each variable with the dependent variable. As the value of t-statistics is 2 or about 2 the level is significant. So, in our case, the value of FDI is 1.71 which is not 2 so the Carbon emissions have an insignificant relationship with the FDI inflows, and the information and communication technologies have the value of -6.14 means there is significance

but negatively influenced and the value of trade openness the value is 5.18 means that there is significant level with the carbon emission. The value of probability is 0.00 which is less than 0.05 which means the results are significant in long-run relationships. The information and communication technologies, FDI inflows, and trade openness have a significant relationship with CO₂. These results also support the previous study of Amri (2018), which stated that the quality of the environment has a significant relationship with information and communications.

References

- Abdoul, M., & Hammami, S. (2017). Economic growth, FDI inflows and their impact on the environment: an empirical study for the MENA countries. *Quality and Quantity*, 51(1), 121–146. <https://doi.org/10.1007/s11355-015-0298-6>
- Ahmed, K., & Ahmed, S. (2018). A predictive analysis of CO₂ emissions, environmental policy stringency, and economic growth in China. *Environmental Science and Pollution Research*, 25(16), 16091–16100. <https://doi.org/10.1007/s11356-018-1849-x>
- Amri, F. (2018). Carbon dioxide emissions, total factor productivity, ICT, trade, financial development, and energy consumption: testing environmental Kuznets curve hypothesis for Tunisia. *Environmental Science and Pollution Research*, 25(33), 33691–33701. <https://doi.org/10.1007/s11356-018-3331-1>
- Asongu, S. A., Nwachukwu, J. C., & Pyke, C. (2019). The comparative economics of ICT, environmental degradation and inclusive human development in Sub-Saharan Africa. *Social Indicators Research*, 143(3), 1271–1297.
- Asongu, S. A. (2018). Comparative sustainable development in sub-Saharan Africa. *Sustainable Development*, 26(6), 638–651.
- Balsalobre-Lorente, D., Driha, O. M., Bekun, F. V., & Osundina, O. A. (2019). Do agricultural activities induce carbon emissions? The BRICS experience. *Environmental Science and Pollution Research*, 26(24), 25218–25234.
- Cetin, B., Aydilek, A. H., & Guney, Y. (2010). Stabilization of recycled base materials with high carbon fly ash. *Resources, Conservation and Recycling*, 54(11), 878–892. <https://doi.org/10.1016/j.resconrec.2010.01.007>
- Coroama, V. C., & Hilty, L. M. (2009, September). Energy Consumed vs. Energy Saved by ICT- A Closer Look. In *EnviroInfo* (2) (pp. 347–355).
- Dhakal, S. (2009). Urban energy use and carbon emissions from cities in China and policy implications. *Energy policy*, 37(11), 4208–4219.
- Frankel, J. A., & Romer, D. (1999). Does trade cause growth? *American Economic Review*, 89(3), 379–399. <https://doi.org/10.1257/aer.89.3.379>
- Geng, Yong & Zhang, Pan & Ulgiati, Sergio & Sarkis, Joseph. (2010). Emergy analysis of an industrial park: The case of Dalian, China. *The Science of the total environment*. 408. 5273–83. [10.1016/j.scitotenv.2010.07.081](https://doi.org/10.1016/j.scitotenv.2010.07.081).
- Gouvea, R., Kapelianis, D., & Kassicieh, S. (2018). Assessing the nexus of sustainability and information & communications technology. *Technological Forecasting and Social Change*, 130, 39–44.
- Hafeez, M., Chunhui, Y., Strohmaier, D., Ahmed, M., & Jie, L. (2018). Does finance affect environmental degradation: evidence from One Belt and One Road Initiative region? *Environmental Science and Pollution Research*, 25(10), 9579–9592. <https://doi.org/10.1007/s11356-018-1317-7>
- Ireland, P., & Clausen, D. (2019). Local action that changes the world: Fresh perspectives on climate change mitigation and adaptation from Australia. In *Managing Global Warming*. Elsevier Inc. <https://doi.org/10.1016/b978-0-12-814104-5.00027-2>
- Ishida, H. (2015). The effect of ICT development on economic growth and energy consumption in Japan. *Telematics and Informatics*, 32(1), 79–88. <https://doi.org/10.1016/j.tele.2014.04.003>
- Kreith, F., Norton, P., & Brown, D. (1990). A comparison of CO₂ emissions from fossil and solar power plants in the United States. *Energy*, 15(12), 1181–1198.

- Latif MT, Othman M, Idris N, Juneng L, Abdullah AM, Hamzah WP et al (2018) Impact of regional haze towards air quality in Malaysia: a review. *Atmos Environ* 177:28–44
- Nizam, H. A., Zaman, K., Khan, K. B., Batool, R., Khurshid, M. A., Shoukry, A. M., Sharkawy, M. A., Aldeek, F., Khader, J., & Gani, S. (2020). Achieving environmental sustainability through information technology: “Digital Pakistan” initiative for green development. *Environmental Science and Pollution Research*, 27(9), 10011–10026. <https://doi.org/10.1007/s11356-020-07683-x>
- Ozcan, B., & Apergis, N. (2018). The impact of internet use on air pollution: evidence from emerging countries. *Environmental Science and Pollution Research*, 25(5), 4174–4189.
- Patterson, B. D., Mo, F., Borgschulte, A., Hillestad, M., Joos, F., Kristiansen, T., Sunde, S., & van Bokhoven, J. A. (2019). Renewable CO₂ recycling and synthetic fuel production in a marine environment. *Proceedings of the National Academy of Sciences of the United States of America*, 116(25), 12212–12219. <https://doi.org/10.1073/pnas.1902335116>
- Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3), 289–326. <https://doi.org/10.1002/jae.616>
- Pickavet, M., Vereecken, W., Demeyer, S., Audenaert, P., Vermeulen, B., Develder, C., ... & Demeester, P. (2008, December). Worldwide energy needs for ICT: The rise of power-aware networking. In 2008 2nd international symposium on advanced networks and telecommunication systems (pp. 1-3). IEEE.
- Rohman, I. K. (2013). The globalization and stagnation of the ICT sectors in European countries: An input-output analysis. *Telecommunications Policy*, 37(4–5), 387–399. <https://doi.org/10.1016/j.telpol.2012.05.001>
- Sahir, M. H., & Qureshi, A. H. (2007). Specific concerns of Pakistan in the context of energy security issues and geopolitics of the region. *Energy Policy*, 35(4), 2031–2037.
- Saud, S., Danish, & Chen, S. (2018). An empirical analysis of financial development and energy demand: establishing the role of globalization. *Environmental Science and Pollution Research*, 25(24), 24326–24337. <https://doi.org/10.1007/s11356-018-2488-y>
- Sims, R. E., Rogner, H. H., & Gregory, K. (2003). Carbon emission and mitigation cost comparisons between fossil fuel, nuclear and renewable energy resources for electricity generation. *Energy policy*, 31(13), 1315–1326.
- Soytas, U., & Sari, R. (2009). Energy consumption, economic growth, and carbon emissions: Challenges faced by an EU candidate member. *Ecological Economics*, 68(6), 1667–1675. <https://doi.org/10.1016/j.ecolecon.2007.06.014>
- Soytas, U., Sari, R., & Ewing, B. T. (2007). Energy consumption, income, and carbon emissions in the United States. *Ecological Economics*, 62(3–4), 482–489. <https://doi.org/10.1016/j.ecolecon.2006.07.009>
- Wang, M., Madden, M., & Liu, X. (2017). Exploring the relationship between urban forms and CO₂ emissions in 104 Chinese cities. *Journal of Urban Planning and Development*, 143(4), 04017014.
- Zhang, C., & Liu, C. (2015). The impact of ICT industry on CO₂ emissions: a regional analysis in China. *Renewable and Sustainable Energy Reviews*, 44, 12–19.
- Zhang, Y. J. (2011). The impact of financial development on carbon emissions: An empirical analysis in China. *Energy policy*, 39(4), 2197–2203.
- Ziemba, E. (2019). The Contribution of ICT Adoption to the Sustainable Information Society. *Journal of Computer Information Systems*, 59(2), 116–126. <https://doi.org/10.1080/08874417.2017.1312635>
- Zoundi, Z. (2017). CO₂ emissions, renewable energy and the Environmental Kuznets Curve, a panel cointegration approach. *Renewable and Sustainable Energy Reviews*, 72, 1067–1075.