Karaki, Bassam Abu; Al-Kasasbeh, Omar; Alassuli, Abdalla et al.

Article

The impact of the digital economy on carbon emissions using the STIRPAT model

International Journal of Energy Economics and Policy

International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2023, 13(5), 139-143.

The Impact of the Digital Economy on Carbon Emissions using the STIRPAT Model

Bassam Abu Karaki[1]*, Omar Al_kasasbeh[2], Abdalla Alassuli[2], Amro Alzghoul[2]

[1]Economics Department, Al-Hussein Bin Talal University, Jordan, [2]Faculty of Business, Amman Arab University, Jordan,

*Email: abukaraki@ahu.edu.jo

Received: 19 April 2023 **Accepted:** 30 July 2023 **DOI:** https://doi.org/10.32479/ijeep.14513

ABSTRACT

As a new economic factor, digitalization plays a vital role in society, economy, and the environment. Based on the expanded STIRPAT model, this paper empirically tests the impact of digital economy on carbon emissions by panel data from 2011 to 2021 in BRICS countries. Utilizing a variety of econometric techniques, the study's objectives were met. For instance, unit root properties are investigated using the CIPS and CADF techniques, while cointegration is examined using the panel cointegration approach of Westerlund and Edgerton (2008). The findings demonstrate the existence of a long-term correlation between carbon emissions, population, GDP, technical level, and digital economy. We propose that governments must not only implement hedging policies to reduce Carbon emissions caused by the digital economy at an early stage but also promote the development of the digital economy in order to accomplish the objective of global collaborative environmental protection.

Keywords: Technical Level, Air Pollution, Westerlund and Edgerton, BRICS
JEL Classifications: C23, L86, Q53, Q561.

1. INTRODUCTION

Climate change has increased the frequency of natural disasters in recent years, which has made the environment more vulnerable. Carbon emissions emitted by fossil fuel combustion are one of the primary causes of climate change (Al-Kasasbeh et al., 2022). Reducing Carbon emissions, constructing a low-carbon society, establishing a green economy, and fostering sustainable development has become the global consensus (Wu et al., 2020).

Computer technology has been maturing since the 1990s. AI, blockchain technology, and 5G technology have spawned numerous new economic models, such as the digital economy. The digital economy is an economic form that guides and realizes the rapid optimal allocation and regeneration of resources and accomplishes high-quality economic development by identifying, selecting, filtering, storing, and utilizing large quantities of data (Ciocoin, 2011).

On April 15, 1998, the U.S. Department of Commerce published the first research report on the digital economy, which concentrated on the crucial role of information as a fundamental resource for macro-and microeconomics. Since then, the digital economy has swiftly become the new millennium's motor of economic growth (Li and Ni, 2021). According to Trade and Development since 2005, the global international trade in digitally delivered services has increased consistently. The export of digitally delivered services increased from USD 918 billion in 2005 to USD 3150 billion in 2019, while the import of these services increased from USD 780 billion in 2005 to USD 2774 billion in 2019. Businesses, consumers, and governments across all economic sectors across the world are realizing the importance of information and communication technology (ICT). Almost every major economy in the world has cited "green" and "digital" as the two buzzwords of important policy directions after reading the COVID-19 economic stimulus plans. Recent economic crises have been met with new chances for sustainable growth and economic recovery thanks to the digital economy, notably ICT as an example of technical advancement (Al-Kasasbeh, 2022).

As a result, the impact of the digital economy on Carbon emissions was investigated in this paper. We incorporated the digital economy as a type of technological progress into the STIRPAT development model and constructed a model of dynamic equilibrium between Carbon emissions and the digital economy. In the early stages of economic development, as a result of the technological advancements brought about by the digital economy, businesses retool production equipment and increase output, thereby increasing Carbon emissions. When the economy develops to a higher level, enterprise output is stable, and the cost of pollution remediation decreases as a result of digitalization, resulting in a decrease in Carbon emissions. Based on the fixed-effects model of the global panel data of BRICS countries from 2011 to 2021. Consequently, this paper examined the impact of the digital economy on Carbon emissions. This paper enriches the theoretical and empirical studies on the impact of the digital economy on Carbon emissions.

2. EMPIRICAL LITERATURE

There are specific studies on the impact of digital economy on carbon emissions, but there is an increasing corpus of research on this topic, including the impact of ICT and Internet use on carbon emissions. Many academics believe that ICTs effectively reduce greenhouse gas emissions. The studies conducted by Ulucak and Danish (2020) on (BRICS) countries between 1990 and 2015 and by Godil et al. (2020) on Pakistan from 1995 to 2018 determined that ICTs significantly reduced CO_2 emissions. Nonetheless, many academics have reached the opposite conclusion. For instance, Raheem et al. (2020) examined G7 countries from 1994 to 2014 and found that ICT contributed significantly to carbon emissions. Chen et al. (2020) analyzed the data of 30 provinces and cities in China from 2001 to 2017 and concluded that informatization played a relatively stable role in promoting carbon emissions, primarily because it fostered the online shopping and takeaway industries in China and led to a significant increase in transportation demand. Similar investigations include Khan et al. (2019), Alkasasbeh et al. (2023), Liu et al. (2021) and Magazzino et al. (2021).

According to Sudoh (2005), with the problem of global environmental degradation becoming increasingly severe, global digital networks, which may link regions around the globe and promote new social norms to overcome nationalist interests, may play an essential role in the long future. This is because global digital networks can link regions around the world and create new social norms to overcome nationalist interests. According to Martynenko and Vershinina (2018), digitization leads to the ecological modernization of production, which not only helps to save a variety of resources but also ensures the continued growth of territories, countries, and the global community as a whole. According to Qian et al. (2020), there is potential for the digital economy and the green economy to mutually benefit one another. To begin, the digital economy has the potential to significantly contribute to the development of a more environmentally conscious global economy. On the other side, the green economy may also aid in the realization of green, low-carbon, and sustainable growth within the digital economy.

The digital economy has negative effects on the environment, despite the Internet's potential to enhance the environment (Sui and Rejeski, 2002). Shvakov and Petrova (2020) analyzed the data of the top 10 countries in the world in 2019 and discovered that digitization hinders the development of a green or energy-efficient economy. On top of that, the implementation of global sustainable development objectives necessitates the limitation of the digital economy's growth rate. Lastly, the digital economy and air pollution have a non-linear relationship. Wu et al. (2021) observed a U-shaped relationship between the digital economy and Carbon emissions by analyzing provincial panel data from 2011 to 2017 in China. In China's developed regions, the digital economy has a positive impact on the environment, while in less developed regions, it has a negative impact. Analyzing the studies on the effects of the digital economy on the environment reveals that the majority of studies are qualitative at this stage. They investigate the environmental impact of the digital economy primarily through descriptive analysis, as opposed to theoretical or mathematical models. Moreover, quantitative studies and empirical evaluations are conducted on specific countries, lacking universality and generalizability. In addition, there is no consensus on whether the digital economy promotes sustainable development. In this paper, we develop a partial equilibrium growth model of Carbon emissions and the digital economy by introducing the digital economy as technological progress based on Bai and Chen, (2020) and Li et al. (2021). Moreover, to determine if the impact of the digital economy on Carbon emissions varies across nations.

3. THE MODEL AND DATA

The IPAT model was first proposed by Ehrlich and Holdren (1971) as a framework for studying the impact of population growth on the environment, with the following model settings:

$$C = P, A, T \tag{1}$$

The IPAT equation does not take into account the differences in the sensitivity of the dependent variables to the influencing factors and cannot observe the impact of factors other than population, affluence, and technology on environmental pressure. In order to overcome the limitations of this model, Dietz and Rosa (1994) established the stochastic form of IPAT-STIRPAT model. According to previous studies, carbon emissions are also influenced by digital economy (Digi). Accordingly, this paper extends the STIRPAT model appropriately:

$$C= P_{it}. A_{it}. T_{it}. Digi_{it}. \varepsilon_{it} \tag{2}$$

Where, C denotes carbon emissions, P_{it} represents the population size of country i at time t, A_{it} represents the economic development level of a region as measured by the gross domestic product (GDP) per capita for the given year, T_{it} represents the region's technical level, as defined by the number of authorized invention patents in each area, and ε_{it} represents the random disturbance item.

Taking the logarithm will compress the variable scale, make the data more stable, and reduce the model's collinearity and heteroscedasticity. However, taking the logarithm will have no effect on the character and correlation of the data. From the standpoint of the research problem, it is necessary to comprehend the effect of each unit change in the influencing factors on carbon emissions. We can convert the multiplication in the model into addition by using logarithms. At this time, the regression coefficient can be explained by the "elasticity" concept in economics, which is useful for analyzing the impact of various influencing factors on carbon emissions. Therefore, we take the logarithm on both sides of model (3) to obtain the following equation:

$$lnC = lnP_{it}.\ lnGDP_{it}.\ lnT_{it}.\ lnDigi_{it}.\ \varepsilon_{it} \quad (3)$$

4. METHODS

This study can be conducted utilising the cross-sectional dependence of the model parameters, and the outcomes will indicate whether the first or second generation of root unit tests is pertinent. In this study, we conducted root tests of the second-generation unit, which were validated by cross-sectional dependency analysis. The integration order of the variables is determined by the unit root analysis, which also reveals their stationary characteristics. In addition, similar to Adekunle (2021) and Quayes (2019), who successfully used unbalanced panel data to conduct sustainability research, we did too. Our data are annual and cover the period 2011-2021 for the following BRICS countries: Brazil, Russia, India, China, and South Africa. To discover the appropriate policy measures for resolving the research problem, which is the study's broad methodological pattern. In the following paragraphs, we describe the specifics of the exams.

4.1. Cross-sectional Dependence Test

As a consequence of intra- and inter-country relationships, panel data typically exhibit cross-sectional dependence (CD). In order to generate consistent and impartial estimates, cross-sectional dependence must be eliminated (Phillips and Sul, 2003). Therefore, it is necessary to investigate the cross-sectional relationship in the panel data. This research investigates CD utilizing two measures proposed by Pesaran (2021) and Baum (2001).

4.2. Panel Unit Root Tests

Before employing cointegration and regression techniques to investigate equilibrium and long-run elasticities among the study's variables, it is crucial to examine the unit root. Prior to this, the unit root test of the first generation, which does not take cross-sectional dependence into consideration, was utilised. Due to their limited capabilities, first-generation evaluations are ineffectual (Dogan and Seker, 2016). Consequently, this study employs root analyses in second-generation systems that comprehend the importance of cross-sectional panel data. This study investigates the unit roots in each component of the analysis using cross-cut IPS (CIPS) and centre augmented Dickey-Fuller (CADF) approaches. These test results are reliable and can be used for further examination.

4.3. Panel Cointegration Test

After confirming the cross-sectional dependence and unit roots in the panel data, it is necessary to ascertain whether the variables are cointegrated. This research employs Westerlund and Edgerton's (2008) cointegration method. This test considers cross-sectional dependence and structural failures in its application. Additionally, it allows for heterogeneity in long-term and short-term error correction models. This research employed the coefficient (ϕN) and t-test version (□N) of cointegration tests, which were derived from LM unit root tests. These two techniques produce reliable results for limited datasets in particular. The descriptive statistics of the variables are shown in Table 1.

5. RESULTS AND DISCUSSION

Before the analysis of econometric estimation, it is better to look at the descriptive statistic of the five variables under consideration. This description is important because it summarizes the properties of the series in the model. Table 1 shows the descriptive statistics for (BRICS). The median values for the independent and dependent variables do not show much dispersion from each other, similarly, to the values of the mean. Furthermore, the table reveals that the standard deviation of the variables are reasonably volatile.

Before evaluating the stationarity of the study variables, we look for evidence of cross-sectional dependence in the panel data. The outcomes of this evaluation, which utilized CD and LM methodologies, are shown in Table 2. These empirical findings demonstrate the existence of cross-sectional dependence between the cross-sections of the panel data by refuting the null hypothesis. In the presence of cross-sectional dependence, the next step is to confirm the sustained existence of each variable. We utilized CIPS and CADF tests for this purpose, and the results are shown in Table 2. According to the results of unit root tests shown in Table 3, it can be seen that the carbon emissions, population, GDP, technical level, and digital economy series were non-stationary and not integrated at the level but became integrated and stationary after taking the first difference.

This paper employs the methodology of Westerlund and Edgerton (2008) to investigate the long-run relationship between the modeled variables in the presence of CD. The method developed by Westerlund and Edgerton (2008) has dual applications for

Table 1: Descriptive statistics of core variables

Variable	Mean	SD	Minimum	Maximum
lnC	0.898	1.413	−3.339	4.006
lnP	10.788	2.571	5.304	17.304
lnGDP	11.210	2.497	6.613	18.133
lnT	21.677	8.805	0.960	86.686
lnDigi	6.391	2.558	−2.613	11.375

Table 2: Cross-sectional dependence tests results

Variable	Breusch-Pagan LM	Pesaran scaled LM	Pesaran CD
lnC	2857.19*	189.79*	46.12*
lnP	1215.80*	73.19*	11.02*
lnGDP	1403.14*	98.93*	38.04*
lnT	1225.12*	68.19*	14.71*
lnDigi	1603.11*	102.02*	18.07*

econometric estimations. In addition to being an efficient method for determining the presence of CD, this method permits the investigation of heterogeneity and serially correlated errors. In addition, this method is suitable for investigating structural fractures in panel data. In this study, the Westerlund and Edgerton (2008) test is preferred because it takes into account cointegration, the possibility of structural break, and heterogeneity, as shown in Table 4. In this method proposed by Westerlund and Edgerton (2008), the cointegration relationship between variables is investigated using three distinct models: no shift, mean shift, and regime shift. According to Table 4, the null hypothesis that there is no cointegration relationship between variables in all models is rejected.

These findings demonstrate the existence of a long-term correlation between carbon emissions, population, GDP, technical level, and digital economy. Theoretically, structural breaks can occur in the presence of any uncertain internal or external disturbance; these shocks have long-term effects on the economy by bringing about enduring changes in socioeconomic determinants (Caglar et al., 2021). Recognising that disruptions can be absorbed if the economy is on a convergence path, the vulnerability of the economic system determines the degree of structural adjustment that would be rapid or gradual towards a convergence or divergence path. In this context, Westerlund and Edgerton (2008) determine the break periods for each country endogenously and separately. Table 5 displays the test results of structural breaks derived from the methodology of Westerlund and Edgerton (2008), which validate the presence of cointegration after the inclusion of structural breaks in the analysis.

Table 3: CIPS and CADF unit root tests result

Variables	CIPS		CADF	
	At level	At first different	At level	At the first different
lnC	−2.954	−3.557*	−2.012	−3.989*
lnP	−2.032	−4. 882*	−2.219	−3.867*
lnGDP	−1.766*	−3.795*	−1.572*	−2.719*
lnT	−2.257	−4.067*	−2.219	−3.867*
lnDigi	−1.719*	−4.002*	−2.072*	−2.342*

*Denotes significant value at 1%

Table 4: Results of Westerlund and Edgerton cointegration test

Model	No shift		Mean shift		Regime shift	
	Statistic	P-value	Statistic	P-value	Statistic	P-value
$LM\phi$	−3.554	0.000	−4.084	0.000	−2.011	0.000
$LM\tau$	−3.916	0.000	−4.064	0.000	−2.502	0.000

Models are run with a maximum number 5 factors

Table 5: Structural breaks of Westerlund and Edgerton cointegration test

Countries	Mean shift	Regime shift
Brazil	2020	2015
Russia	2015	2016
India	2020	2021
China	2019	2019
South Africa	2021	2015

6. CONCLUSION

At the onset of digitalization, firms produce more products as a result of technological advancement, resulting in greater carbon emissions than those reduced by digitalization. When the level of digitalization is high, the amount of carbon treated is greater than the amount of carbon emitted, as firms produce products at a constant rate and technological progress leads to a green economy. How does the digital economy influence global warming? This paper examined the relationship between the digital economy and carbon emissions. This paper empirically evaluates the impact of digital economy on carbon emissions in (BRICS) countries from 2011 to 2021. To attain this objective, the study began the empirical analysis by determining if a CD exists in the data. After identifying CD in the series, we conducted the CIPS and CADF second-generation unit root tests and determined that all variables are first-order stationary. Due to the heterogeneous character of the five countries analysed, we employed the Westerlund and Edgerton (2008) method with the assumption that various breakpoints exist in series.

Based on the findings of this investigation, we propose several pertinent policy implications. First, the development of the digital economy will increase carbon emissions at the onset of digitalization. To prevent industrial carbon emissions, governments must implement hedging policies to mitigate the negative effects of the digital economy. Carbon emissions can be effectively reduced when the digital economy reaches a certain level of development. To accomplish the objective of global collaborative environmental protection, all nations should adhere to the development of the digital economy in order to shorten the period of early pollution caused by it and make greater use of it.

REFERENCES

Adekunle, I.A. (2021), On the search for environmental sustainability in Africa: The role of governance. Environmental Science and Pollution Research, 28(12), 14607-14620.

Al-Kasasbeh, O., Alzghoul, A., Alhanatleh, H. (2022), Empirical analysis of air pollution impacts on Jordan economy. International Journal of Energy Economics and Policy, 12(4), 512-516.

Alkasasbeh, O., Khasawneh, O., Alzghoul, A. (2023), The nexus between renewable energy consumption and economic growth: Empirical evidence from Jordan. International Journal of Energy Economics and Policy, 13(2), 194-199.

Al-Kasasbeh, O.M. (2022), The emergence of digital economy and new business models in the Era of digital transformation. New Innovations in Economics, Business and Management, 7, 161-168.

Bai, L., Chen, X. (2020), Research on the synergy of green economy and digital economy in stimulus policies. Journal of Dongbei University of Finance and Economics, 131, 73-81.

Baum, C.F. (2001), Residual diagnostics for cross-section time series regression models. The Stata Journal, 1(1), 101-104.

Caglar, A.E., Mert, M., Boluk, G. (2021), Testing the role of information and communication technologies and renewable energy consumption in ecological footprint quality: Evidence from world top 10 pollutant footprint countries. Journal of Cleaner Production, 298, 126784.

Chen, F., Zhao, T., Liao, Z. (2020), The impact of technology-environmental innovation on CO_2 emissions in China's transportation sector. Environmental Science and Pollution Research, 27, 29485-29501.

Ciocoiu, C.N. (2011), Integrating digital economy and green economy: Opportunities for sustainable development. Theoretical and Empirical Researches in Urban Management, 6(1), 33-43.

Dietz, T., Rosa, E.A. (1994), Rethinking the environmental impacts of population, affluence and technology. Human Ecology Review, 1(2), 277-300.

Dogan, E., Seker, F. (2016), The influence of real output, renewable and non-renewable energy, trade and financial development on carbon emissions in the top renewable energy countries. Renewable and Sustainable Energy Reviews, 60, 1074-1085.

Ehrlich, P.R., Holdren, J.P. (1971), Impact of population growth. Obstetrical and Gynecological Survey, 26(11):769-771.

Godil, D.I., Yu, Z., Sharif, A., Usman, R., Khan, S.A.R. (2021), Investigate the role of technology innovation and renewable energy in reducing transport sector CO_2 emission in China: A path toward sustainable development. Sustainable Development, 29(4), 694-707.

Khan, S.A.R., Sharif, A., Golpîra, H., Kumar, A. (2019), A green ideology in Asian emerging economies: From environmental policy and sustainable development. Sustainable Development, 27(6), 1063-1075.

Li, X., Liu, J., Ni, P. (2021), The Impact of the digital economy on CO_2 emissions: A theoretical and empirical analysis. Sustainability, 13(13), 7267.

Li, Y., Yang, X., Ran, Q., Wu, H., Irfan, M., Ahmad, M. (2021), Energy structure, digital economy, and carbon emissions: Evidence from China. Environmental Science and Pollution Research, 28, 64606-64629.

Liu, X., Latif, Z., Latif, S., Mahmood, N. (2021), The corruption-emissions nexus: Do information and communication technologies make a difference? Utilities Policy, 72, 101244.

Magazzino, C., Mele, M., Morelli, G., Schneider, N. (2021), The nexus between information technology and environmental pollution: Application of a new machine learning algorithm to OECD countries. Utilities Policy, 72, 101256.

Martynenko, T.S., Vershinina, I.A. (2018), Digital economy: The possibility of sustainable development and overcoming social and environmental inequality in Russia. Revista Espacios, 39(44), 12.

Pesaran, M.H. (2021), General diagnostic tests for cross sectional dependence in panels. Empirical Economics, 60(1), 13-50.

Phillips, P.C., Sul, D. (2003), Dynamic panel estimation and homogeneity testing under cross section dependence. The Econometrics Journal, 6(1), 217-259.

Qian, L., Fang, Q., Lu, Z. (2020), Research on the synergy of green economy and digital economy in stimulus policies. Southwest Finance, 413, 3-13.

Quayes, S. (2019), Probability of sustainability and social outreach of microfinance institutions. Economics Bulletin, 39(2), 1047-1056.

Raheem, I.D., Tiwari, A.K., Balsalobre-Lorente, D. (2020), The role of ICT and financial development in CO_2 emissions and economic growth. Environmental Science and Pollution Research, 27(2), 1912-1922.

Shvakov, E.E., Petrova, E.A. (2020), Newest trends and future scenarios for a sustainable digital economy development. In: Scientific and Technical Revolution: Yesterday, Today and Tomorrow. New York: Springer International Publishing, p1378-1385.

Sudoh, O. (2005), The knowledge network in the digital economy and sustainable development. In: Digital Economy and Social Design. Germany: Springer. p3-38.

Sui, D.Z., Rejeski, D.W. (2002), Environmental impacts of the emerging digital economy: The E-for-environment E-commerce? Environmental Management, 29, 155-163.

Ulucak, R., Khan, S.U.D. (2020), Does information and communication technology affect CO_2 mitigation under the pathway of sustainable development during the mode of globalization? Sustainable Development, 28(4), 857-867.

Westerlund, J., Edgerton, D.L. (2008), A simple test for cointegration in dependent panels with structural breaks. Oxford Bulletin of Economics and Statistics, 70(5), 665-704.

Wu D, Wang Y, Qian, W. (2020), Efficiency evaluation and dynamic evolution of China's regional green economy: A method based on the super-PEBM model and DEA window analysis. Journal of Cleaner Production, 264, 121630.

Wu, Y., Luo, C., Luo, L. (2021), The impact of the development of the digital economy on Sulfur Dioxide emissions: Empirical evidence based on provincial panel data. Journal of Wuhan Polytechnic, 20, 82-88.