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Digital Technologies, Environmental Governance and Environmental Performance: Empirical Evidence from China

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This research conducts an empirical analysis of the relationship between digital technologies, environmental governance (assessed through environmental taxes), and China's environmental performance from 1995 to 2020. Additionally, within the framework of the STIRPAT model, the impacts of GDP and urbanization on ecological footprints are examined. This study is distinguished by its innovative approach to evaluating environmental performance via ecological footprints and the application of the Autoregressive Distributed Lag (ARDL) model along with Dynamic Ordinary Least Squares (DOLS), Canonical Cointegration Regression (CCR), and Fully Modified Ordinary Least Squares (FMOLS) as long-run estimators, methodologies not previously applied to this context in China. The findings indicate that digital technologies and environmental taxes contribute to a reduction in ecological footprints, while GDP and urbanization have an adverse effect, increasing ecological footprints. Post-estimation diagnostics confirm the absence of serial correlation and heteroskedasticity, and affirm the normal distribution of the disturbance terms. For a robustness check, the study further employs DOLS, FMOLS, and CCR methods, which corroborate the initial results regarding the beneficial impact of digital technologies and environmental governance on ecological footprints. Based on these findings, the study advises the Chinese government and policymakers to enact more effective environmental tax policies and leverage digital technologies to enhance environmental sustainability in China.

Keywords: *Digital Technologies; Environmental Governance; Ecological Footprints; China.*

Introduction

The cost that humans are paying for the world's modernity in terms of the deterioration of the environment is significant. The fact is that the global temperature is increasing. The burning of fossil fuels, which releases greenhouse gases, with CO2 being the most significant contributor, being the main cause of this global warming. Due to harsh weather, rising sea levels, droughts, health issues, and other factors, the future of the globe is seriously threatened by rising carbon and other greenhouse gas emissions (York *et al.*, 2022). The issue of dust storms, light pollution, haze pollution, and noise pollution is significantly more prevalent than ever before due to the rapid economic growth. Environmental protection receives increased attention and is a hot topic as ecological pollution gravely threatens public health (Al-Tamimi & Al Anssari, 2022; Aliedan, 2022; Arieftiara *et al.*, 2022; He, Zhang *et al.*, 2019; Noja *et al.*, 2023; Xiao *et al.*, 2023; Zheng, 2023).

Consequently, scholars and environmentalists are exploring factors that can simultaneously reduce carbon emissions and support global economic expansion. In response to this imperative, several countries have progressively established mechanisms for environmental protection, enacting various policies aimed at mitigating environmental degradation and improving the natural ecosystem. (Appiah-Kubi *et al.*, 2023; Bagazi, 2022; Braicic, 2021; Chen *et al.*, 2022; Chernus, Sivkov *et al.*, 2022; Clauss *et al.*, 2021; Dai *et al.*, 2022; Streimikiene & Mikalauskiene, 2023; Sun & Shi, 2023).

The impact of the environmental governance should not be underestimated among all those. Products that negatively affect the environment, especially on finite natural resources, may be subject to governed by environmental taxes. Environmental governance encourages the consumption of low energy and low carbon goods. Environmental rules encourage firms to use eco-friendly technology throughout the production process (Prosper *et al.*, 2023). Environmental taxes are specialized tax regulations with the goal of lowering energy-related pollution emissions and having a negative ecological footprint. The basic aim of these tax policies is to ensure environmental performance, economic effectiveness, and much less resource use (energy consumption, for example), through which many goals related to reducing air emissions, water pollution, water disposal, and other factors related to climate change are achieved (Burrichter *et al.*, 2022). By encouraging the manufacturing industry to implement efficient technology or make ecologically friendly goods or products, these taxes can enhance environmental quality. Ecological governance discourages destructive environmental behaviours and aid in the achievement of sustainable development (Damodharan & Ahmed, 2022; Dung *et al.*, 2022; Fakhrou *et al.*, 2022; Griffioen, 2022; Huang *et al.*, 2022; Khamzin *et al.*, 2022; Rafique *et al.*, 2022).

Similarly, digital technologies such as ICTs, that has completely changed human society, has made contributions to the environment. These technologies now have a significant role to play in growth of developed and emerging countries (Acha-Anyi *et al.*, 2020; Agboola, 2006; Al-

Mulali, Ozturk, & Lean, 2015; Kim & Curtin, 2022; Kore *et al.,* 2022; Korotaj & Mrnjaus, 2021; My *et al.,* 2022; Orero-Blat *et al.,* 2021). Additionally, the function of ICT has expanded to include banking and finance (Asongu *et al.,* 2018; Asongu *et al.,* 2019; Orero-Blat *et al.,* 2021; Pereira *et al.,* 2022; Phundeamvong & Suttawet, 2022; Seidu *et al.,* 2022), health care (Asongu *et al.,* 2021; Bahmani-Oskooee & Harvey, 2015; Bahmani-Oskooee & Hegerty, 2007), education (Asongu & Andres, 2020), energy (Bastida *et al.,* 2019), and industries (Bahmani-Oskooee *et al.,* 2016). ICT is widely used in advanced economies, therefore its contribution to economic growth cannot be disregarded. However, its contribution to environmental pollution is questionable (Cardona *et al.,* 2013). The impact of ICTs is growing and the world's energy consumption because of ICT-related products is rising at a high rate of 7 % per year throughout the last few years (Chaabouni & Saidi, 2017). In 2012, this figure was 4.7 %, up from 3.9 % in 2007 (Chemutai, 2009). As a result, the ICT sector's overall contribution to world CO2 emissions had reached 2 % (Chen *et al.,* 2019). Because the manufacture of materials connected to ICTs pollutes the environment, the share of ICT industry in CO2 emissions is rising (Chen *et al.,* 2019). However, as more people use the internet, mobile devices, laptops, etc., the demand for energy has increased, which the primary factor causing the environmental quality to decline(Usman *et al.,* 2021; Wilson-Mah & Bernardes, 2022).

ICT, on the other hand, is regarded as a way to strengthen the protection of the environment, to reduce the negative environmental effects of human activity, and to cope up with some major environmental problems like climate change and sustainability. By raising the awareness about environmental problems and using ecologically friendly technology, ICT may also help to reduce environmental damage (Lashkarizadeh & Salatin, 2012). ICT applications aid in risk management and risk prediction connected to the environment. Solutions based on ICT are found to be beneficial for the sustainability of environment because they reduce pollution emissions (Uddin & Rahman, 2012). The term "transition from supplying physical things to offering online services" refers to the dematerialization impact of ICT". For instance, when e-mail usage increased, less paper is utilized and fewer communications have been sent physically. Similarly, the growing adoption of cutting-edge technology like internet telephony and video conferencing has given businesses and society a number of chances to reduce commuting, hence reducing emissions. Additionally, growing e-banking and e-commerce usage is enabling internet transactions, which reduces need for physical transportation and thus lowers greenhouse gas emissions (Drawert *et al.,* 2022). ICT is assisting in the provision of intelligent automated solutions in a number of areas, including electricity production, agriculture, and industry, in addition to reducing dependence on physical travel. ICT is therefore regarded as a low carbon enabler and a crucial factor in determining environmental sustainability, which can help reduce carbon emissions in a variety of industries like transportation, buildings and electricity generation (Majeed, 2018).

Similar to the ambiguous relationship between ICT and environmental performance, there is disagreement on whether environmental regulations such as taxes have a negative, positive, or either of these effects on environmental degradation (Sun *et al.,* 2022). These facts motive the researches to further study the effect of ICT and environmental taxes on environmental performance. Additionally, a fundamental limitation of previous researches is that the majority of them only consider the nexus between environmental taxes and pollutant emissions, such as the association between CO2 and sulphur dioxide emissions and air quality (Ozokcu & Ozdemir, 2017), (Dogan *et al.,* 2019; Hao *et al.,* 2020). This study estimates the environmental performance in terms of ecological footprints. Ecological footprint is a more complete environmental indicator since it captures the use of natural resources for human activities and measures environmental issues brought on by resource use and therefore has gained more attention recently compared to CO2 emissions (Sun *et al.,* 2022). A biologically productive region was used to quantify the ecological footprint (Wackernagel & Rees, 1998). Global Footprint Network (2020) reports that during the past 50 years, the ecological footprint has expanded by about 190 %, reaching 1.73 times of the ecological carrying capacity in 2017. The expansion of the ecological footprint has the potential to negatively impact ecosystems and contribute to environmental issues like climate change and air pollution (Pata & Yilanci, 2020). As a result, numerous academics have investigated the origins of environmental problems (Chen *et al.,* 2022).

The primary objective of this research is to examine the impact of environmental governance (quantified through environmental-related taxes) and Information and Communication Technology (ICT) on the ecological footprints in China during the period from 1995 to 2020. As the world's largest economy, China stands at the forefront in terms of income, energy consumption, environmental footprints, waste production, and emissions. Given China's escalating environmental footprint and increasing levels of pollution, the authors are motivated to conduct an empirical analysis on the effects of environmental taxes and ICT within the Chinese context. As illustrated in Fig. 1, there is a noticeable surge in China's ecological footprints coinciding with the growth in per capita GDP. Despite the rapid expansion of China's GDP, the country's ICT industry and telecommunications sector were relatively under-developed in the early 1990s, experiencing significant growth only in the subsequent decades post-1990. (Shahzad et al., 2022). As of January 2018, China's first environmental protection tax law went into force, signaling that the country has begun the process of establishing environmental protection through the imposition of environmental-related taxes on businesses. Instead of being a voluntary action, this fee transforms environmental conservation into a legally enforceable policy. Although China has pioneered environmental taxation, the structure and method are still in their infancy (He, Zhang et al., 2019). In addition to assisting the government in formulating sound strategic plans for the ICT industry, empirical research on the connection between ICT and ecological footprints in China also contributes to the body of literature.

There are three ways that this study can contribute to the body of literature and help guide policy decisions. First and foremost, this study is unique because it makes a unique effort to clarify how digital technologies, environmental taxation, and environmental performance are related in China. Second, unlike earlier studies that consider GHG or CO2 emission as a measure of environmental performance, the present study uses ecological footprints as a measure of environmental performance that has never been used before in the context of China to explore the nexus between digitalization, environmental taxes and environmental performance. Third, to guarantee the accuracy of our findings, we employed a variety of estimation techniques and cointegration regression models (ARDL, DOLS, FMOLS, and CCR). The study concluded with recommendations and suggestions for creating policies that will effectively promote environmental performance. Researchers, politicians, environmentalists, and governments will find the study's conclusions beneficial in their work to create a sustainable environment by the responsible use of digital technology and environmental taxes.

We organize the study in the following sequence: Section 2 provides literature review. data and empirical methodology are described in Section 3. Section 4 is about results and discussions and section 5 gives conclusion of the study and policy implications.

Literature Review

ICT and Environmental Performance

Numerous studies have been done that highlight the importance of ICT in assuring environmental performance. A good structural change brought about by appropriate ICT use results in a variety of environmentally friendly technical advancements. On the other side, it has been noted that ICT use directly degrades environmental quality by sharply increasing pollutant emissions. ICT usage and disposal are increasing, which increases energy consumption and lowers environmental performance (Batool *et al.,* 2022). Out of empirical studies, (Lee & Brahmasrene, 2014) studied the nexus between CO2 emission, ICT and economic growth by for a panel of ASEAN countries and using cointegration analysis. The authors revealed positive association of ICT on CO2 emission and economic growth. (Usman *et al.,* 2021) studied the asymmetric and non linear impact of ICT on environmental performance measured by CO2 emission in top 9 Asian countries and found that ICT had linear and non linear significant impact on CO2 emission in countries. Raheem, Tiwari, and Balsalobre-Lorente (2020) scrutinized the data of G7 countries and studied the impact of ICT and financial development on CO2 emissions. According to the primary findings of Pooled Mean Group, ICT had positive contribution in increasing emissions while the interaction effect of financial development and ICT was negative on CO2 emission. (Batool *et al.,* 2022) estimated the effect of ICT on CO2 emission in East and South developing economies and used PMG estimation approach. According to findings, ICT promoted environmental degradation by increasing carbon emissions.

For Pakistan, (Godil, Sharif, Agha, & Jermsittiparsert, 2020) studied the impact of financial development, institutional quality and ICT on CO2 emission using QARDL estmation approach. The findings showed that institutional quality and ICT had negative impact on carbon emission. For China, (Chi & Meng, 2022) explored the effect of ICT on CO2 emission in different provinces and municipalities and concluded that ICT reduced CO2 emission in System GMM estimation. (Kongbuamai *et al.,* 2022) studied the nexus between ICT and ecological footprints in N-11 countries by applying Feasible Generalized Least Squares and Driscoll-Kraay standard errors and found that ICT had positive association with ecological footprints in N-11 countries. (Raza *et al.,* 2022) analyzed the role of ICT in ecological footprints in Pakistan and QARDL findings revealed significant impact of ICT on ecological footprints.

Environmental Taxes and Environmental Performance

Environmental taxes have a crucial role in reducing negative environmental effects such, GHG emission, haze pollution and CO2 emissions (Balsalobre-Lorente & Leitao, 2020; Lobao & Costa, 2020). Previous studies have extensively analyzed implications of environmental taxes in environmental performance, like (Chien *et al.,* 2021) analyzed the effect of environmental taxes and eco-innovations on carbon emissions and PM.2.5 emission and according to the CS-ARDL analysis findings, authors identified positive contribution of environmental taxes and eco-innovations in reducing pollution emission in top Asian countries. (Rafique *et al.,* 2022) studied the relationship between ecological footprints and environmental taxes in 29 OECD countries by using Fixed Effects, DOLS and FMOLS models. The authors found positive contribution of environmental taxes in ecological footprints reduction in OECD economies. (Dogan *et al.,* 2022) explored the direct and moderating role of environmental taxes on natural resources, carbon emissions and energy consumption in G-7 countries and concluded that environmental taxes significantly declined CO2 emission. For a panel of 20 European economies, (Wolde-Rufael & Mulat-Weldemeskel, 2022) studied the role of environmental policy stringency and environmental taxes on carbon emission over 1995–2012 period. it was found that there was significant positive impact of environmental taxes and environmental stringency policy on carbon emission in selected countries. (Dogan *et al.,* 2022) studied the effect of green growth and environmental taxes on CO2 emissions in top 25 environmentally sustainable countries. the study indicated that environmental taxes and green growth were the key factors for reducing carbon emissions in studied countries.

In continuation, despite panel studies, several individual countries were also considered by previous scholars as case studies to explore environmental taxes and environmental performance nexus. Out of these, (Chien *et al.,* 2021) considered the data of the USA to explore the nexus between, green growth, environmental taxes, ecological innovations and CO2 emission by applying QARDL approach. Positive contribution of green growth, environmental taxes and ecological innovations was observed in reducing CO2 emission over different quantiles. (Yu *et al.,* 2022) explored the association between environmental related taxes and pollution emission and green growth in China. ARDL approach was used and negative association was found between environmental taxes and CO2 emission and positive association was found between green growth and environmental taxes. (He *et al.,* 2019) made a comparative study of China and Sweden over 1980-2016 period by applying ARDL-ECM approach to estimate the environmental taxes effect on environmental quality and economic growth. The findings showed no significant of environmental taxes on CO2 emission but positive effect on economic growth in China. For Malaysia, (Loganathan *et al.*, 2014) studied the impact of environmental related taxations and economic growth on carbon emission and found no significant impact of environmental taxes on carbon emission in ARDL Bound testing approach. In another study for Malaysia, (Loganathan *et al.*, 2020) tried to study the nexus between environmental taxation and environmental quality by using boostrap quantile estimation and found that environmental taxes reduced carbon emissions in higher quantiles. (Telatar & Birinci, 2022) analyzed the non linear nexus between environmental taxes and CO2 emission and ecological footprints in Turkey and found no significant effect of taxes on ecological footprints and CO2 emission.

Literature Gap

The examination of current literature indicates that while numerous studies have assessed the impact of digital technologies and environmental taxes on environmental quality, the research specifically focused on this interplay within the context of China is limited. Furthermore, previous investigations primarily utilized CO2 emissions as a proxy for environmental performance, rather than adopting the more holistic measure of ecological footprints. Additionally, the Autoregressive Distributed Lag (ARDL) method has been the prevalent approach among researchers for empirical analysis of these relationships. By recognizing and addressing these gaps, this study emerges as a unique contribution to the literature.

Data and Methodology

The analytical model that is most effective for analyzing how the environment reacts to anthropogenic factors is the STIRPAT model given by (Dietz & Rosa, 1994). Due to its ability to support many functional forms, it is very beneficial for empirical analysis. Additionally, it permits the inclusion of additional regressors as control variables, which is a very advantageous feature. As a result, STIRPAT is a multivariate nonlinear model. In its simplest form, it is defined as:

$$I_i = \alpha P_i^{\beta} A_i^{\gamma} T_i^{\delta} \varepsilon_i \quad (1)$$

I denotes environmental quality, population is represented by P, A and T denote Affluence and technology respectively. α shows intercept term and δ, ɣ and β denote exponents, i and ε are observations and error terms.

The added logarithmic formulation of the aforementioned equation is displayed as:

$$logI_i = \alpha + \beta logP_i + \gamma logA_i + \delta logT_i + \varepsilon_i \quad (2)$$

The study makes use of the modification of Equation (2) depicted in Equation (3) as:

$$EF_t = \beta_0 + +\beta_1 ICT_i + \beta_2 GDP_t + \beta_3 URB_t + \varepsilon_t \quad (3)$$

Where EF denotes ecological footprint, ICT denotes digitalization, GDP denotes GDP per capita and URB shows urbanization, ε represents error term. In the aforementioned model (3), the ecological footprints are used to assess environmental quality, ICT is used to assess technology, and urbanisation is used to assess the population component of the STIRPAT model. Economic growth serves as a measure of affluence A. following (Rafique *et al.*, 2022), (Telatar & Birinci, 2022), (Dogan *et al.*, 2022) and (Chien *et al.*, 2021) we extended our model by adding environmental taxes in the following form.

$$EF_t = \beta_0 + \beta_1 ICT_t + \beta_2 GDP_i + \beta_3 URB_t + \beta_4 ET_t + \varepsilon_t \quad (4)$$

Where, ET denotes environmental taxes.

The following Table 1 gives all information regarding variables, including measurement and data sources.

Table 1

Variables and Sources of Data

Variable/Series	Measurement	Data Source
Ecological Footprints	Global hectors per capita	Global Footprint Network
ICT	ICT index comprising of Mobile Subscription (per 100 people) + Fixed broadband subscriptions (per 100 people) + Telephone subscription (per 100 people)	WDI
Environmental governance	Environmental related taxes	OECD
Urbanization	Urban population (as % of total population)	WDI
Economic Growth	Gross domestic product per capita ($ 2015 constant)	WDI

Estimation Techniques

The study uses the ARDL model, developed by (Pesaran *et al.*, 2001) which is a most appropriate estimating tool to show both the short run and the long run relationships between the model variables. Compared to earlier cointegration approaches, this technique has a number of benefits. Other cointegration techniques require the estimation of the integration property of series, whereas this method does not require any such preliminary testing. Moreover, we can use ARDL model to account for endogeneity by taking the lag length of the variables into consideration. Second, it can also be used in any situation involving the integration of research series. Finally, despite having little observations, the ARDL model still remains valid (Raihan & Tuspekova, 2022a). The ARDL bound testing approach can be written using the econometric model provided in Equation (3), as shown in (4).

$$\Delta EF_t = \alpha_0 + \alpha_1 EF_{t-1} + \sum_{i=1}^{l} \alpha_2 \Delta ICT_{t-i} + \sum_{i=1}^{m} \alpha_3 \Delta GDP_{t-i} + \sum_{i=1}^{o} \alpha_4 \Delta URB_{t-i} + \sum_{i=1}^{q} \alpha_5 \Delta ET_{t-i} + \beta_1 ICT_{t-1} + \beta_2 GDP_{t-1} + \beta_3 URB_{t-1} + \beta_4 ET_{t-1} + \varepsilon_t \quad (4)$$

Where, Akaike Information Criterion is used to estimate the lag orders denoted by l, o, m, q.

The following step involves determining if the study's endogenous and exogenous variables or series are cointegrated after selecting the optimum ARDL model with the help of a traditional lag length criterion. This technique for analyzing cointegration is far more accurate than any other potential techniques for determining the existence of cointegration as it performs efficiently regardless of the order of integration. Therefore, this technique is utilized to test the cointegration of several endogenous and exogenous variables. This test contrasts the alternative hypothesis of cointegration among the variables to the null hypothesis of the absence of it in order to examine cointegration. Comparisons between the lower and upper critical bounds and F statistic are made. Cointegration is found if the estimated value of the F statistic is higher than upper bound. The result of the test does not provide any clear conclusion if the F statistic value lies between lower bound and upper bound. In contrast, no cointegration is suggested if the F statistic value is smaller than that of lower bound value.

We then estimate the model's short- and long term parameters. The functional form of the model of study in the long run is shown in equation (5).

$$\Delta EF_t = \sigma_0 + \sum_{i=1}^{l} \sigma_1 EF_{t-1} + \sum_{i=1}^{m} \sigma_2 ICT_{t-i} + \sum_{i=1}^{o} \sigma_3 GDP_{t-i} + \sum_{i=1}^{q} \sigma_4 URB_{t-i} + \sum_{i=1}^{p} \sigma_0 ET_{t-i} + \varepsilon_t \quad (5)$$

After establishing the long run link between the series, the coefficients for the short run needs to be obtained. In order to get the coefficients, we evaluated the error-correction mechanism, as shown in Equation (6).

$$\Delta EF_t = \varphi_0 + \sum_{i=1}^{l} \varphi_1 \Delta EF_{t-1} + \sum_{i=1}^{m} \varphi_2 \Delta ICT_{t-i} + \sum_{i=1}^{o} \varphi_3 \Delta GDP_{t-i} + \sum_{i=1}^{q} \varphi_4 \Delta URB_{t-i} + \sum_{i=1}^{p} \varphi_5 \Delta ET_{t-i} + \varphi_5 ECT + \varepsilon_t \quad (6)$$

The aforementioned equation shows the dynamics of error-correction and long-term connections between the series. In Equations (v) and (vi), Δ is the first difference operator. Additionally, the terms "ECT" and " φ " stand for the error correction term and coefficient, respectively.

In order to assess the model's robustness, we also used the FMOLS, DOLS, and CCR to examine how various variables throughout time impacted the EF output. The requirement to use these techniques was caused by two key considerations. Before using the FMOLS, DOLS, or CCR, the requirement of cointegration among the parameters must first be satisfied. Second, these estimations address biases in endogeneity and serial correlation that result from the cointegration. It produces results with asymptotic efficiency as a consequence (Raihan & Tuspekova, 2022b).

Results and Discussions

Table 2 lists the primary characteristics of data, including average, standard deviation, and maximum and minimum values. GDP has the highest average value of any series, whereas ET is having the lowest mean value. Among all the variables with the highest variability around the mean, GDP has the highest minimum and maximum values. However, among all the series, the lowest mean, data range and standard error values are of ET.

Table 2

Summary/ Descriptive Statistics Results

Series	Mean	Standard. deviation	Max	Min	J-B Stats
EF	1.5588	0.5255	2.3990	0.9160	2.0919***
ICT	51.064	20.688	85.9710	13.707	3.4048***
GDP	5300.68	3106.87	1118.33	1520.20	6.453***
URB	46.488	10.004	62.512	30.961	2.888***
ET	0.97	0.41	1.68	0.15	3.872***
*** shows P<0.05					

This main objective of the research is to study how the variables under discussion have a long run relationship. For the purposes of using the techniques to establish a long run relationship, the unit root test testing gives essential information on the integration order of the series. Therefore, two of traditional root tests, such as the ADF and Philips-Perron (PP) tests, are applied to study the integration properties of the series. Table 3 provides a summary of the findings of the stationarity or unit root tests test. All series display the unit root problem at level before becoming stationary after the first difference, according to the conventional tests of unit root output.

Table 3

PP and ADF Tests

	ADF		PP	
Level	**Intercept**	**Intercept and Trend**	**Intercept**	**Intercept and Trend**
EF	-2.732	-2.409	-1.113	-1.084
ICT	-1.643	-0.434	-0.551	-0.876
GDP	-5.762	-2.717	4.987	-2.367
URB	-2.042	-2. 113	-3.098	-2.685
ET	-2.171	-1.372	-2.169	-1.361
first difference				
EF	-4.431***	-4.545***	2.871***	3.445**
ICT	-3.823***	-3.098***	-4.021***	-3.113***
GDP	- 3.533***	- 2.432***	-2.224***	-5.117***
URB	-2.053***	-4.512***	-2.667***	-3.331***
ET	-3.651***	-4.874***	2.943***	-2.680***

, **, and * indicate 1, 5, and 10 significance level respectively.*

We discovered that the series under investigation is an I(1) series based on our observations of the unit root. In order to estimate the long run and the short run linkages among the series of the study, we used the ARDL-based bounds testing approach. We chose to use the AIC as our lag specification because our model consistently produced good results for each alternative's information criterion. Table 4 demonstrates that the estimated cointegration analysis F-statistic (4.97) is much greater than the upper critical threshold. Thus, we draw the conclusion that cointegration exists between the independent variable and the regressors.

Table 4

Findings of ARDL Bound Testing

Statistics	**Value**	**K**
F-statistics	4.97	3
Critical bounds values		
Significance level	I0	I1
10 percent	2.92	3.56
5 percent	4.34	4.63
2.5 percent	3.59	3.99
1 percent	3.49	4.07

The ARDL long- and short-run estimation results are shown in Table 5.

Table 5

Long Run and Short Run ARDL Results
Dependent Variable: EF

	Long Run			**Short Run**		
Series	**Coefficients**	**t-statistcs**	**Prob-value**	**Coefficients**	**t-statistics**	**P rob-value**
ICT	-0.567***	-2.713	0.043	-0.340***	-3.235	0.061
GDP	0.134***	2.098	0.022	0.117***	2.499	0.061
URB	0.097**	2.087	0.034	0.085***	2.541	0.024
ET	-0.125**	-2.060	0.067	-1.436**	-2.550	0.025
ECT(-1)	-0.873***	-5.859	0.001			

, ** & * shows 10, 5 and 1 significance level respectively.*

First of all, the empirical results indicate that ICT had negative and significant effect on ecological footprints in China. For every unit increase in ICT index, there will be reduction of 0.56 and 0.34 units in EF in the long run and short run. Thus the finding of the study demonstrate that more use of digital technologies have beneficial impacts on environmental performance of China. This finding is supported by (Khan *et al.*, 2018) for developing countries, (Godil *et al.*, 2020) for Pakistan, (N'dri *et al.*, 2021) for developing countries and (Yi & Thomas, 2007), (Zhang & Liu, 2015) for China. The finding implies that ICT offers some direction to lessen the negative effects of human activity on the environment. by reducing the need for transportation, e-commerce can help minimize the usage of petroleum. As ICT advances, more meetings and transactions are being conducted electronically, which reduces energy use and, eventually, environmental destruction.

The empirical findings showed a statistically significant and positive GDP coefficient, which suggests that a rise in GDP of 1 unit causes a rise in ecological footprints of 0.134 units over the long run and 0.117 units over the short term. Thus the findings of the current study demonstrate that, as the economy expands as measured by the gross domestic product, so does the incentive to raise ecological footprints. According to this argument, China's quick economic growth has adverse environmental impacts both now and in future. This shows that China's attempts to boost its economy using non-environmentally friendly methods are ineffective in achieving the nation's goal of carbon neutrality. This finding is consistent with (Raihan & Voumik, 2022) for China, (Udemba, 2020) for Nigeria, (Ahmad *et al.*, 2021) for Group of 7 economies, (Jun *et al.*, 2022) for top emitter economies and (Hanif *et al.*, 2022) for ASEAN countries.

Next, the estimation's findings suggest that environmental tax has a positive impact on environmental quality. A 1 unit increase in ET causes EF to decline by 0.125 units in long run and 1.43 units in short run suggesting that environmental regulations serve as an extra expense that can deter the manufacturing of hazardous pollutants (Hao *et al.*, 2021) (He *et al.*, 2019). To reduce this cost and limit environmental externalities, businesses typically use environmentally friendly equipment and technologies. The analysis by (He *et al.*, 2019) for G-7, (Vera & Sauma, 2015) for China, (Sen & Vollebergh, 2018) for the OECD economies, (Yunzhao, 2022) for E-7 countries and (Chien *et al.*, 2021) for Asian countries also supports this mechanism. A government's dedication to the objectives of sustainable development is also demonstrated by a high environmental tax rate. The environmental tax revenue is then used to fund research and the development of green technologies.

And last, the coefficient of urbanization is positive and significant both in the long and short run. ecological footprints increase by 0.097 units in the long run and 0.085 units in the long run for each unit increase in ecological footprints. (Martinez-Zarzoso & Maruotti, 2011) for developing countries, (Ali *et al.*, 2019) for Pakistan, (Bekhet & Othman, 2017) for Malaysia and (Sadorsky, 2014) for emerging economies also observed the similar mechanism. In general, urbanization affects ecological footprints through industrial and residential energy use, through energy consumed in the construction industry for building better transportation, housing and infrastructure, and through the conversion of woodlands and grasslands to make way for urban development. Additionally, it is found that ECT has highly negative effect. With yearly basis adjustments of 87 %, this estimate of 0.87 demonstrated how the short- term equilibrium altered as it progress toward a stable long term equilibrium. It proved the effectiveness of the feedback mechanism in preserving China's environmental sustainability.

As demonstrated in Table 6 of the diagnostic test findings, the residuals followed a normal distribution without any indications of misspecification, and there was no evidence of heteroskedasticity or serial correlation in the residuals.

Table 6

Diagnostics Test Findings

Tests	Coefficients	Prob-value	Decision
Heteroskedasticity Test	1.0876	0.376	Homoskedasticity is present
Serial Correlation	1.3256	0.817	No serial correlation is present
Normality Test	0.287	0.324	Error terms are normally distributed

The model was shown to be stable at 5 % level of significance according to the cumulative sum and cumulative sum of squares stability tests results, which are shown in Figure 1 and Figure 2.

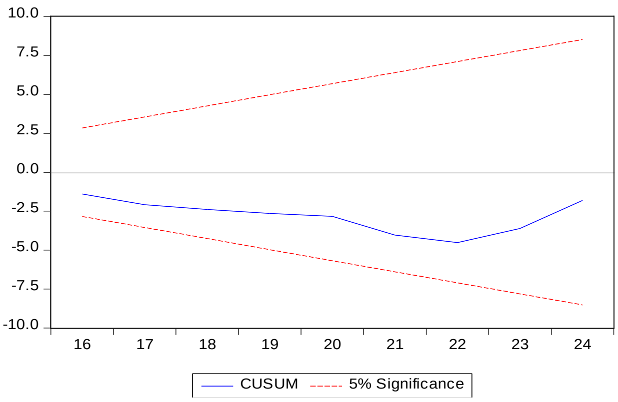

Figure 1. CUSUM test results

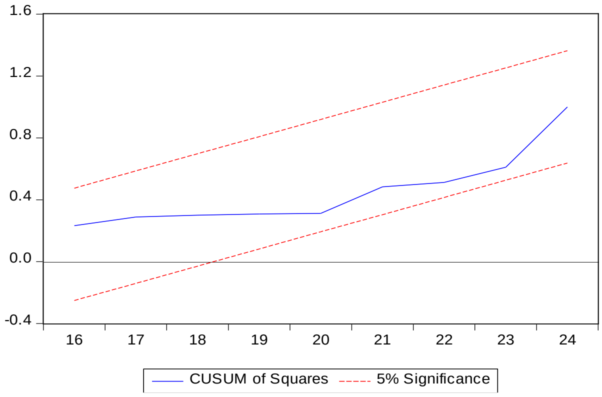

Figure 2. CUSUMQ test results

Using the DOLS, CCR and FMOLS tests, the ARDL framework's findings are also examined over a long period of time. The estimated outcomes from the application of DOLS, FMOLS and CCR are shown in Table 7. The DOLS, CCR and FMOLS findings are all demonstrated to have consistent and reliable signs. As a result, they eventually produce the same outcomes as the ARDL computations. The information specifically demonstrates that rising GDP and urbanization increase ecological footprints while rising environmental taxes and digital technologies decrease ecological footprints. As a result, judgments based on the findings can be made with considerable degree of assurance.

Table 7

Robustness Analyses Findings

Series	F-MOLS		D-OLS		CCR	
	Coefficients	Prob value	Coefficients	Prob value	Coefficients	Prob value
ICT	-0.098**	0.087	-0.413**	0.098	-1.297***	0.008
GDP	1.333**	0.060	0.973***	0.009	0.642**	0.068
URB	0.629***	0.054	0.811***	0.004	0.078***	0.000
ET	-0.324	0.032	-0.473***	0.012	-0.322***	0.041
C	22.56***	0.000	3.876**	0.071	2.948**	0.089
R^2	0.876		0.894		0.864	
Adjusted R^2	0.856		0.887		0.851	

Conclusion and Policy Recommendations

This research examines the role of digitalization and environmental governance on China's environmental performance using data from 1995 to 2020. The study holds its novelty by estimating environmental performance in terms of ecological footprints which has never been used earlier in the context of China to study the nexus between digitalization, environmental goevrnance and environmental performance. In addition, under STIRPAT model, GDP and urbanization are also for their impact on ecological footprints. To confirm the robustness of the results, the study used the ARDL model together with the FMOLS, DOLS, and CCR long-run estimators. The results of the study show that digital technologies and environmental taxes reduce ecological footprints, whereas GDP and urbanization increase ecological footprints. The post estimation diagnostic tests reveal the absence of serial correlation and heteroskedasticity and provide evidence for the normal distribution of disturbance terms. For robustness check, the study applies DOLS, FMOLS and CCR also. The findings of these approaches also validate the negative impact of digital technologies and environmental taxes on ecological footprints. Thus it is concluded from the study that use of digitalization and environmental taxes can help China to perform better in terms of environmental sustainability.

The results of this investigation could have significant policy implications. The findings suggest that China must increase its use of digital technologies to stop environmental deterioration. Through ICT-based solutions to energy intensity, commuting, and resource use, better ICT use can result in enhanced environmental quality. Moreover, Chinese government must strengthen its environmental tax policy. Environmental taxations, if properly implemented, will greatly help the country reach its environmental performance goal. For this purpose, the adoption of a significant environmental regulation like the carbon tax can be more helpful at halting environmental damage than anticipating an indirect impact from taxes like expenditure tax and wealth tax. Pollution and resource taxes, which are costs on carbon-emitting resources, incentivize producers and consumers to use environmentally friendly sources. It will Encourage citizens and investors to favour ecologically friendly goods and services. These measures will assist in transition of the entire economy in favour of the environment, in addition to assisting China in creating a sustainable environment.

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