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GREENHOUSE GAS EMISSIONS, INBOUND TOURISM DEMAND, AND INFORMATION AND COMMUNICATION TECHNOLOGY: WHERE IS THE LINK?

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Abstract: The world experiences an increase in greenhouse gas emissions linked to human activities such as information and communication technology (ICT) and tourism activities. The aim of this study is to investigate the effects of ICT and inbound tourism demand on greenhouse gas emissions in South Africa. The study involved annual time series data (1989-2020), and this data was analysed using autoregressive distributed lag (ARDL) and Granger causality models. The empirical results indicate that a 1% increase in inbound tourism demand causes the level of greenhouse gas emissions to increase by 0.52% in the long-run, but inbound tourism demand has no short-run effect on greenhouse gas emissions. On the other hand, ICT only has a short-run effect on greenhouse gas emissions. The results also show that there is a unidirectional causal relationship between greenhouse gas emissions to ICT and inbound tourism demand.

Key words: Greenhouse gas emissions; ICT; Inbound tourism demand; ARDL; Granger causality; South Africa

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INTRODUCTION

The tourism industry has established itself as a major contributor to the economies of countries across the world, both developed and developing countries. The total contribution of the tourism industry to the global economy hovered around US$10 trillion (10.4% of the global GDP) in 2019, but the contribution declined in the subsequent year owing to the COVID-19 pandemic (World Travel and Tourism Council [WTTC], 2022). However, the tourism industry is blamed for contributing to the level of greenhouse gas emissions in the atmosphere. Reports indicate that tourism generated more than 8% of the global greenhouse gas emissions between 2009 and 2013 (Dunne, 2018; Sustainable Travel International, 2020), and it projected that greenhouse gas emissions from the tourism industry will increase by 25% between 2016 and 2030 (UN World Tourism Organisation [UNWTO], 2019). Most tourism-related greenhouse gases are emitted by transport and energy consumption in tourist accommodations.

The increase in greenhouse gas emissions in the tourism industry is linked to the growing tourism demand (Lenzen et al., 2018), and this increase in the emissions of greenhouse gases may intensify as global tourism demand is on the rise again after the COVID-19 pandemic, which crippled the tourism industry because of domestic and international travel restrictions imposed by governments across the world. The pandemic hit the tourism industry hard, but evidence shows that the greenhouse gas emissions linked to tourism declined significantly during the pandemic (Nagaj and Žuromskaitė, 2021). In Spain, for example, the level of greenhouse gas emissions declined by 63% in 2020 in relation to pre-pandemic levels of greenhouse gas emissions (Osorio et al., 2023). Sharing the same sentiment with Lenzen et al. (2018), reducing tourism carbon emissions is highly improbable given that the measures taken by countries to stimulate tourism demand outstrip the measures taken to mitigate tourism greenhouse gas emissions.

Countries are vehemently competing to develop and market tourism destinations in attempts to lure large numbers of tourists. However, there are views that the advancements of ICT play a pivotal role in decelerating the emissions of greenhouse gases (Asongu, 2018; Danish, 2019; Melson, 2022; Wei and Liu, 2023; Wen et al., 2022; Zafar et al., 2023). This implies that tourism establishments may curb the emissions of carbon dioxide by embracing ICT in their operations. The role of ICT in restraining greenhouse gas emissions in the tourism industry, however, is still unexplored.

This study aims at investigating the effects of information and communication technology (ICT) and inbound tourism demand influence greenhouse gas emissions. There is sparse literature related to the effects of ICT on greenhouse emissions in the tourism industry. This is the existing lacuna in literature this study envisaged to fill, using time series data for South Africa. The choice of South Africa as a case study is based on the vibrancy and development of the country's tourism industry. South Africa is among the top five most visited countries in Africa, alongside Egypt, Morocco, Tunisia, and Algeria (Dzinduwa, 2022; Obiero, 2022; Pariona, 2017). In fact, the country is the most preferred destination in the entire Sub-Saharan region, receiving an annual average of 10 million international tourists. In 2019, the country lured 10.2 million international tourists despite the threat of COVID-19 (South African Tourism, 2019). The country's ITC sector is also developed and the largest on the African continent, leading in computers, mobile, and software (Gillwald et al., 2018). The remainder of this paper is divided into four sections, which are literature review, methodology, findings and discussion, and conclusion.

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LITERATURE REVIEW

1. The link between tourism and greenhouse gas emissions

Greenhouse gas emissions have become a topical research area in the past few decades, following the increasing and devastating impacts of climate change on humans and the environment. There are sizeable studies on the causes of greenhouse gas emissions (Anser et al., 2021; Basarir and Çakir, 2015; Kwakwa et al., 2023). The chief causes of greenhouse gas emissions are human activities such as transport, farming, and tourism (Lenzen et al., 2018). A number of reports and empirical studies have shown that the tourism industry contributes to greenhouse gas emissions (Abeydeera and Karunasena, 2019; Basarir and Çakir, 2015; Daniels, 2018; Koçak et al., 2020; Sharma, 2022; Yu-Guo and Zhen-Fang, 2014). Between 2009 and 2013, for example, the tourism industry emitted around 8% of total global greenhouse gases, and tourism's share in greenhouse gas emissions is projected to rise as tourism demand is swelling across the world (Lenzen et al., 2018). Greenhouse gas emissions in the tourism industry are caused by transport, catering, accommodation, and other activities that use a huge amount of energy and emit carbon dioxide into the atmosphere (Tang et al., 2014), but among tourism activities, transport takes the lead in emitting greenhouse gases (Daniels, 2018; Sharma and Ghoshal, 2015; World Tourism Organisation [WTO], 2003, Yu-guo and Zhen-fang, 2014). In the US, for example, 76% of the total greenhouse emissions linked to tourism activities come from transport (WTO, 2003). In attempts to lessen greenhouse gas emissions caused by tourism transport, strategies such as promoting domestic tourism and travelling short distances, using land transport instead of air and water transport, staying longer at destinations, and reducing travel frequency were proposed (Perch-Nielsen et al., 2010; Unger et al., 2016).

The level of the contribution of tourism to greenhouse emissions varies from country to country, and from one region to another. A high volume of tourism-related greenhouse gas is emitted in and by developed countries (Lenzen et al., 2018) because these countries have a developed tourism industry. The US is the leading tourism-related greenhouse gas emitter due to a considerable number of both inbound and outbound tourists in the country, but greenhouse gas emissions in middle-income countries like China, Brazil, and India are exponentially increasing as the citizens of these countries become more interested in travelling to other countries (Coghlan, 2018). There is a link between tourist flows and greenhouse gas emissions. A study conducted in China, for example, reported that an increase in tourist arrivals between 1990 and 2012 resulted in an increase in greenhouse gas emissions (Tang et al., 2014). This link between increased tourist arrivals and high greenhouse gas emissions needs no sophisticated explanation. An increasing number of tourist arrivals consumes high energy, which also leads to increased greenhouse gas emissions (Rehman et al., 2022). A study conducted in 32 OECD countries, however, shows a bidirectional causal relationship between tourist arrivals and greenhouse gas emissions in some countries like Canada, and a unidirectional causal relationship from tourist arrivals to CO_2 emissions in countries such as Chile, Germany, Ireland, and Latvia (Balli, 2021). Similar results were reported by Irfan et al. (2023) indicating that all sub-sectors of the tourism industry Granger cause most of the greenhouse gas emissions in China.

2. The link between ICT and greenhouse gas emissions

The relationship between the advancement in ICT and greenhouse gas emissions is easily discernible considering the influence of ICT on human activities, including energy consumption, production, and service delivery (Anser et al., 2021; Hernández et al., 2020; Lefophane and Kalaba, 2020; World Meteorological Organisation, 2022), which are major contributors of greenhouse gas emissions to the atmosphere. The argument is that the application of ICT in human activities influences the emission of greenhouse gases. A substantial number of earlier empirical studies have affirmed the link between the application of ICT and greenhouse gas emissions (Ahmed et al., 2021; Atsu et al., 2021; Park et al., 2018; Malmodin et al., 2010). However, there is no consensus among studies on whether the advancement in ICT application diminishes or raises greenhouse gas emissions. Some studies indicate that the advancement in the use of ICT results in an increase in greenhouse gas emissions (Atsu et al., 2021; Malmodin et al., 2010; Su et al., 2021), whereas other studies oppose these results, affirming that ICT and its application play a pivotal role in reducing greenhouse gas emissions (Asongu, 2018; Avom et al., 2020; Danish, 2019). Specifically, Malmodin et al. (2010) found that the information and communication technology sector alone generated 1.3% of global greenhouse gas emissions in 2007. In 2020, it was reported that the ICT sector alone used 4% of the global electricity, which is approximately 1.4% of the global greenhouse gas emissions (Malmodin et al., 2023). The positive influence of ICT on CO_2 was also reported by Simpson et al. (2019), whose study involved panel data for 113 countries. Their results indicated that the use of fixed telephones and the internet is linked to higher CO_2 emissions in developed countries. It is argued that the effects of fixed telephones and the internet, which are proxies of ICT on greenhouse gas emissions, are low in developing countries because developing countries have limited fixed telephone and internet connections.

A study conducted in BRICS countries (Brazil, Russia, India, China, and South Africa) also reveals that high technology experts and electric power consumption result in high CO_2 emissions (Su et al., 2021). Similarly, a study conducted in South Africa reveals that carbon dioxide (CO_2) emissions increase by 0.565% in the long term when fixed telephone subscriptions increase by 1%, whereas CO_2 emissions go up 0.255% when fixed telephone subscriptions increase by 1% in the short run (Atsu et al., 2021). A study conducted in China also found that the level of greenhouse gas emissions goes up by 0.205% when ICT increases by 1% (Liu and Wan, 2023). On the one hand, Danish (2019) found that the advancement in ICT plays a vital role in curbing the emissions of greenhouse gases. Similar to this result, Asongu's (2018) findings suggest that applying ICT may diminish the negative effects of globalisation on CO_2 emissions. For example, virtual services may be offered without people traveling to service providers. The COVID-19 pandemic galvanised some tourism destinations to offer virtual guided tours without tourists travelling to the destinations physically (Repo and Pesonen, 2022). In their study conducted in 77 countries, Al-Mulali et al. (2015) found that internet shopping mitigates greenhouse gas emissions, but this mitigation was found in developed countries. Yet, Chatti (2021) argued that employing

ICT in the transport sector has the potential to reduce air pollution. Based on the above empirical literature, the role of ICT in reducing CO_2 emissions is no longer disputable. However, arguing that increasing greenhouse gas emissions promotes the advancement of ICT and its application is sensible. ICT applications may be developed in attempts to find solutions to the increasing emissions of greenhouse gases. This argument is supported by Appiah-Otoo et al. (2022), whose findings indicate that there is bi-directional causality between CO_2 and ICT in countries that have a high and moderate quality of ICT, and there is unidirectional causality from CO_2 to ICT in countries that have a low quality of ICT.

3. The relationship between ICT and tourism

ICT in the tourism industry plays a profound and fundamental role in different ways, ranging from linking tourism service providers with customers and other key stakeholders to improving production and quality service delivery (Anser et al., 2021; Khan and Hossain, 2018; Nikoli and Lazakidou, 2019; Sardar et al., 2021; Trivedi et al., 2018). The advancement in ICT application in the tourism industry enables tourism service providers including destinations and individual tourism businesses to market and sell their products and services to potential tourists, irrespective of time and geographical location (Khan and Hossain, 2018; Trivedi et al., 2018), denoting that long distance between service providers and tourists is no longer an obstacle. Gritta and Calabrese (2023) reported interesting results which show that digital marketing enables small businesses in Italy to succeed in the country and abroad. To this end, tourists who are technologically empowered can view and purchase tourism products online at their convenience without physical contact with tourism service providers (Khan and Hossain, 2018), leading to increased tourism demand and revenue. Empirical studies affirm that incorporating ICT in tourism has positive effects on tourism growth (Adeola and Evans, 2020; Kumar and Kumar, 2020; Kumar, 2013; Sharma et al., Mohapatra and Giri, 2022). For example, Sharma et al. (2022) found that foreign tourist arrivals in India grow by 1.40% in the long run if ICT application increases by one unit. Similarly, Kumar and Kumar (2020) reported that a 1% in broadband subscriptions and mobile subscriptions causes foreign tourist arrivals to increase by 0.11% and 0.04%, respectively.

Based on these findings and the findings of other studies, such as Lee et al. (2021), and Roy and Ahmed (2019), it is unequivocal that embracing ICT in the tourism industry brings many benefits to the industry. However, the argument that ICT benefits from the tourism industry to some extent is sensible. Factors such as competition and changes in behaviour and preferences of tourists may require tourism service providers to invest in new technologies that may foster innovation and creativity for them to remain or become competitive. Similar to this argument, Adeola and Evans (2019) report a bidirectional causality between tourism and ICT, particularly internet usage and mobile penetration. Wagaw and Mulugeta (2018) also found that the intention to use ICT in the tourism sector increases when the technology is believed to heighten competitive advantage. The use of information and communication technology in tourism is also sparked by factors such as the attractiveness and location of tourist destinations (Sardar et al., 2021). Nevertheless, the role of the tourism industry in advancing ICT continues to be overshadowed by the contribution of ICT to tourism. Consequently, this study aims to determine whether there is a symbiotic relationship between tourism growth and information and communication technology.

METHODOLOGY

a. The description of data

The study used 32 annual observations, starting from 1989 to 2020, and this sample period was dictated by the availability of data. The data is made up of three variables, which are greenhouse gas emissions, inbound tourism demand, and information communication and technology accessed from the World Bank Development Indicators. The dependent variable is greenhouse gas emissions (GHG), whereas information communication and technology (ICT) and inbound tourism demand (TA) are independent variables. The greenhouse gas emissions index is measured by total greenhouse gas emissions (kt of CO_2 equivalent); the inbound tourism demand index is represented by foreign tourist arrivals; and the index for ICT is measured by indices of three proxies, which are mobile cellular subscriptions, individuals using the internet (% of the population), and fixed telephone subscriptions. One single and robust index for ICT was constructed by applying principal component analysis (PCA). This analysis was used to overcome the problem of multicollinearity in variables. Adeola and Evans (2020) argue that PCA solves the problems of multicollinearity. Similarly, Dunteman (1989) advises that PCA can be used to improve the precision of regression results of the original variables in case there is multicollinearity among variables. However, all variables were transformed into natural logarithm form before conducting any tests to increase the reliability of results. The descriptive statistics and correlation matrix of the study variables are depicted in Table 1.

Table 1. Descriptive statistics and correlation matrix

Statistics	LNGHG	LNICT	LNTA
Mean	13.00509	-0.049287	15.68438
Median	13.04716	-0.008033	15.76242
Maximum	13.23723	0.000000	16.16423
Minimum	12.68841	-0.213193	14.35174
Std. Dev.	0.190074	0.062180	0.437978
Skewness	-0.343208	-0.984327	-1.253179
Kurtosis	1.616756	2.670997	4.206083
Jarque-Bera	3.179374	5.311788	10.31529
Probability	0.203989	0.070236	0.005755
Sum	416.1629	-1.577184	501.9001
Sum Sq. Dev.	1.119977	0.119857	5.946560
Observations	32	32	32

Correlation matrix

LNGHG	1.000000		
LNICT	0.787092	1.000000	
LNTA	0.801306	0.571727	1.000000

b. Model specification

To determine the long-run relationship among the study variables, the autoregressive distribution lag (ARDL) model by Pesaran and Shin (1995) was employed, after conducting unit root tests to determine whether the study variables meet the criteria for the ARDL model. The rule of thumb is that the ARDL model is applied only if there no study variables are stationary at second difference I(2) (Pesaran et al., 2001). The model is applied when study variables are stationary at level I(0) or at the first difference I(1), or when some variables are stationary at I(0) and others are stationary at I(1). To determine the stationary of variables, the augmented Dickey-Fuller (ADF) and Phillips and Perron (PP) tests were conducted. The initial model used to test the relationship between greenhouse gas emissions, tourism growth, and information and communication technology is expressed as:

$$GHG = f(TA, ICT) \tag{1}$$

Where GHG is greenhouse gas emissions, f is a functional notation, TA represents tourism growth measured by tourist arrivals, and ICT represents information and communication technology. After transforming the study variables into natural logarithm (LN), the above model becomes:

$$LNGHG = f(LNTA, LNICT) \tag{2}$$

The ARDL model specification for the relationship between the independent and dependent variables is derived from the above model (2), and the new model is as follows:

$$LNGHG_t = \alpha_0 + \varphi_j LN\,GHG_{t-i} + \delta_j LN\,TA_{t-i} + \beta_j LN\,ICT_{t-i} + e_t \tag{3}$$

Where α_0 denotes a constant, $LN\,GHG_{t-i}$ represents the value of greenhouse gas emissions in natural logarithm at time t, $LN\,TA_{t-i}$ symbolises the value of tourist arrivals in natural logarithm at time t, and $LN\,ICT_{t-i}$ represents the value of information and communication technology in natural logarithm. The coefficients of the long-run relationship are represented by φ_j, δ_j, and β_j. And e_t stands for the error correction term. Then, the regression equation for testing the cointegration is expressed below:

$$\Delta LNGHG_t = \alpha_0 + \Sigma_{j=1}^{k}\varphi_j \Delta LNGHG_{t-j} + \Sigma_{j=1}^{k}\delta_j \Delta LNTA_{t-j} + \Sigma_{j=1}^{k}\beta_j \Delta LNICT_{t-j} + \Sigma_{j=1}^{k}\gamma_j \Delta LNGHG_{t-j} + \Sigma_{j=1}^{k}\omega_j \Delta LNTA_{t-j} + \sigma_j LNICT_{t-1} + e_t \tag{4}$$

In the above equation, Delta (Δ) indicates a change in the value of variables, whereas γ_j, ω_j, and σ_j represent the coefficients of the short-run relationship. The bounds cointegration was tested based on the following hypotheses:

H_0: $\varphi_j = \delta_j = \beta_j = 0$, suggesting that there is no cointegration among the variables.

H_1: $\gamma_j \neq \omega_j \neq \sigma_j \neq 0$, suggesting that there is a long-run relationship among the variables.

The bounds for the cointegration test were conducted to test the existence of a long-run relationship. The value of the calculated F-statistic was compared against the critical values of both lower bound I(0) and upper bound I(0) to determine whether there is a long-run relationship among the variables. It is concluded that there is a long-run relationship among variables if the calculated F-statistic value is above the critical values of the upper bound, meaning that the H_0 is rejected. On the other hand, the H_0 is not rejected if the value of the calculated F-statistic is below the critical values of the lower bound. In case the calculated F-statistic value falls between the critical values of lower and upper bounds, the result is inconclusive, implying that it may not be concluded that there is a long-run or there is no long-run relationship (Pesaran et al., 2001). The existence of a long-run relationship, because of the calculated F-statistic, paves the way for determining the adjustment of the disequilibrium caused by short-run shocks. The adjustment is established using the error correction model (ECM). The equation used for establishing the adjustment is expressed as follows:

$$\Delta LNGHG_t = \alpha_0 + \Sigma_{j=1}^{k}\varphi_j \Delta LNGHG_{t-j} + \Sigma_{j=1}^{k}\delta_j \Delta LNTA_{t-j} + \Sigma_{j=1}^{k}\beta_j \Delta LNICT_{t-j} + \Sigma_{j=1}^{k}\gamma_j \Delta LNGHG_{t-j} + \Sigma_{j=1}^{k}\omega_j \Delta LNTA_{t-j} + \sigma_j LNICT_{t-1} + ECT_{t-1} + e_t \quad (5) \tag{5}$$

Where ECT_{t-1} denotes the error correction term. Residual diagnostic and stability tests were conducted to establish the validity and stability of the ARDL model in the study. The presence of a long-run relationship galvanised a further analysis. The paired Granger causality test was carried out to determine the causal relationship among the study variables.

EMPIRICAL RESULTS AND DISCUSSION

1. Results of unit root tests

Two unit root tests (PP and ADF) were conducted to determine whether there no study variable is stationary at I(2). The results of both tests presented in Table 2 below indicate that the variables are a combination of I(0) and 1(1). No variable is stationary at second difference, I(2). Since the results meet the precondition for applying the ARDL model, the model was applied to investigate the relationship among the variables.

2. Results of F-bounds cointegration and long-run tests

The results from F-bounds cointegration test (Table 3) reveal that the value of the computed F-statistic (28.93269) is much higher than the critical values of the upper bounds at the 10%, 5%, 2.5%, and 1% significance levels. These results led to a conclusion that there is a long-rung relationship among the study variables, meaning that the null hypothesis that there is no long-run relationship among the variables was rejected. Based on these results, the effects of information communication and technology, and inbound tourism demand on greenhouse gas emissions in the long run were determined. The results of the long-run test reveal that changes in the use of ICT do not have effects on the emission of greenhouse gases in the atmosphere (Table 4). The coefficient (-0.003756) of ICT has a negative sign, but it is not statistically significant at the 5% level, denoting that any changes in ICT as measured by internet users and subscribers of mobile phones and fixed telephone lines do not have an effect on the level of greenhouse emissions in South Africa in the long run. These results are different from the results of previous studies that indicate that advancement in technology leads to high greenhouse gas emissions (Atsu et al., 2021; Su et al., 2021). To be precise, a previous study conducted in South Africa revealed that CO_2 emissions go up by 0.565% in the long run when the number of fixed telephone users grows by 1% (Atsu et al., 2021). On the other side of the coin, other studies found that an increase in ICT reduces greenhouse emissions (Asongu, 2018; Danish, 2019).

The emissions of greenhouse gases in the atmosphere in South Africa are influenced by inbound tourism demand. A 1% increase in inbound tourism as measured by foreign tourist arrivals leads to a 0.52% increase in greenhouse gas emissions. This influence is not surprising given that an increase in the arrival of international tourists implies that substantial amounts of CO_2 were transmitted in the air by airlines and other means of transport used by the tourists visiting South Africa. This result supports the results of earlier studies that also suggested that the tourism industry contributes to the increasing greenhouse gas emissions in the atmosphere (Abeydeera and Karunasena, 2019; Daniels, 2018; Koçak et al., 2020; Sharma, 2022). Increased tourist arrivals are also linked to high consumption of energy by tourists and tourist facilities (Rehman et al., 2022).

Table 2. Unit root test results

Variable	Integration orders		LNGHG	LNICT	LNTA
PP (t-values)	I(0)	Intercept	-1.149345	-1.613895	-2.140826
		Trend & intercept	-3.937257	-1.864450	-2.703712
	I(1)	Intercept	-6.544308*	-5.299909*	-5.101401*
		Trend & intercept	-6.687603*	-5.826933*	-4.873911*
ADF (t-values)	I(0)	Intercept	-1.098276	-1.893984	-2.167845
		Trend & intercept	-3.497921	-4.240783*	-2.752203
	I(1)	Intercept	-6.519463*	-5.100786*	-5.137694*
		Trend & intercept	-6.254172*	-5.062994*	-4.995119*
Order of integration			I(1)	I(1)	I(1)

Table 3. Results of F-bounds cointegration test

F-Bounds Test	Null hypothesis: No levels relationship			
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	28.93269	10%	2.63	3.35
k	2	5%	3.1	3.87
		2.5%	3.55	4.38
		1%	4.13	5

Table 4. Results of long-run test

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNICT	-0.003756	0.479708	-0.007829	0.9938
LNTA	0.517228	0.071889	7.194859	0.0000
C	4.925607	1.141807	4.313870	0.0002

3. Results of short-run test

The short-run results reveal that inbound tourism demand has no effect on greenhouse gas emissions, implying that the level of greenhouse gas emissions remains unchanged in the short run irrespective of an increase or a decrease in foreign tourist arrivals. Surprisingly, a positive effect of information communication and technology on greenhouse gas emissions was detected. Greenhouse gas emissions increase by 0.61% in the short run if the application of ICT increases by 1% (Table 5). This result supports the result of a previous study that indicated that the use of ICT contributed 1.3% to CO_2 emissions in 2007 (Malmodin et al., 2010). It was also found that greenhouse emissions have a lagged effect.

The level of greenhouse gas emissions contracts by 0.3% (0.295520) in the current year because of the increase of 1% in the previous year. Since there is a long-run relationship among the series, there was a need to apply the error correction model in an attempt to determine the period needed for correcting disequilibrium in the long-run. The result shows that the coefficient (-0.300561) of the error correction term (ECT) is statistically significant at the 5% level and has a negative sign as expected (Table 5). The interpretation of this coefficient is that 30% of the disequilibrium is corrected each year. This speed (30%) of adjustment to equilibrium is relatively slow. Therefore, 3.327116 (1/0.300561) years, implying three years and four months are required for the disequilibrium to be adjusted.

Table 5. Results of short-run tests and ECT

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(LNGHG(-1))	-0.295520	0.064717	-4.566345	0.0001
D(LNICT)	0.610884	0.113053	5.403524	0.0000
CointEq(-1)	-0.300561	0.026341	-11.41039	0.0000

Table 6. Results of residual diagnostic test

Test	**Null hypothesis**	**Prob.**
Breusch-Godfrey Serial Correlation LM Test	No serial correlation	0.2813
Breusch-Pagan-Godfrey Heteroskedasticity test	Homoskedasticity	0.9378
Jarque-Bera Normality test	No normality	0.4453

4. Results of residual diagnostic and stability tests

To determine the reliability of the model used for the data analysis, residual diagnostic and stability tests were conducted. Residual diagnostic tests are autocorrelation, heteroscedasticity, and normality, whereas stability tests are cumulative sum (CUSUM) and cumulative sum of square (CUSUMSQ). The results from residual diagnostic tests affirm that there is no autocorrelation and heteroscedasticity in the series. The results also indicate that the series are normally distributed as depicted in Table 6. Therefore, the results are accurate and valid. The stability test, on the other hand, shows that CUSUM and CUSUMSQ (blue lines) in Figure 1 and Figure 2 remained within the critical boundaries throughout the sample period at the 5% level of significance. The results led to the conclusion that the model was stable.

5. Results of paired Granger causality test

The current results reveal that inbound tourism demand and ICT do not granger cause the emissions of greenhouse gas in the atmosphere. Basarir and Çakir (2015), however, found that tourist arrivals granger cause greenhouse gas emissions. The results show only a unidirectional causal relationship running from greenhouse gas emissions to inbound tourism demand and to ICT (Table 7).

Table 7. Paired Granger causality test results

Null Hypothesis:	Obs	F-Statistic	Prob
LNICT does not Granger cause LNGHG	30	0.29886	0.7443
LNGHG does not Granger cause LNICT	30	7.41523	0.0030
LNTA does not Granger cause LNGHG	30	0.29309	0.7485
LNGHG does not Granger cause LNTA	30	9.45006	0.0009
LNTA does not Granger cause LNICT	30	2.36286	0.1148
LNICT does not Granger cause LNTA	30	2.55476	0.0978

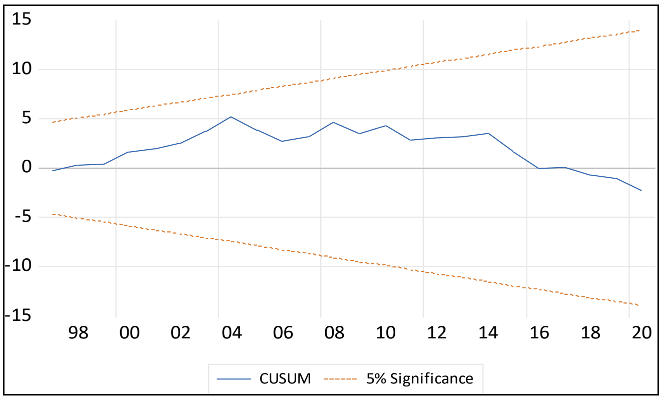

Figure 1. CUSUM result

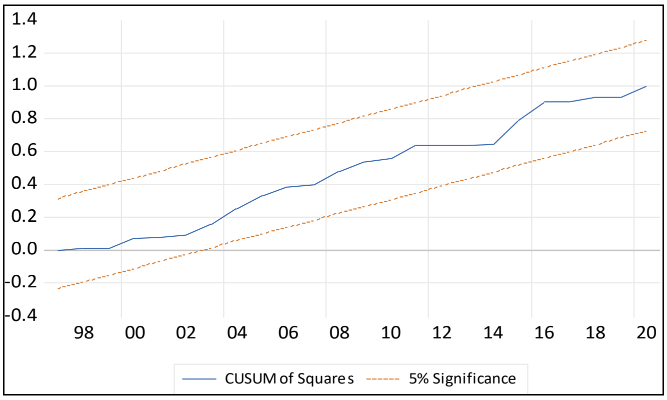

Figure 2. CUSUMSQ result

But a study conducted by Koçak et al. (2020) reveals that tourism development (measured by tourist arrivals and tourist receipts) and greenhouse gas emissions have a bidirectional causality relationship. The causal relationship from greenhouse gas emissions towards ICT is justifiable. Increasing greenhouse emissions may galvanise governments and businesses to invest in ICT and its application in attempts to slow down the increase in greenhouse gas emissions. Similar to this argument, a study conducted by Al-Mulali et al. (2015) also found that greenhouse gas emissions in developed countries reduce if online shopping increases. A previous study conducted in India indicates that information and communication technology granger causes foreign tourist arrivals (Sharma et al, 2022), but the results of the current study show that ICT does not granger cause inbound tourism demand in South Africa (Table 7).

The null hypothesis that ICT does not granger cause tourist arrivals was not rejected as the p-value is statistically insignificant at 5% level, indicating that there is no causal relationship moving either from tourist arrivals to information and communication technology (ICT) or from ICT to tourist arrivals. This result contradicts the findings of Adeola and Evans (2019) which show that mobile penetration, internet, and tourism in Africa have a bidirectional causal relationship.

CONCLUSION

Studies on the effects of ICT and inbound tourism demand on greenhouse gas emissions report contracting results. Findings of some studies show that an increase in ICT or inbound tourism demand increases the emissions of greenhouse gases in the atmosphere, whereas other studies reveal that advancements in ICT reduce greenhouse gas emissions. There are even studies that suggest that a growing level of greenhouse gas emissions prompts an increase in the use of ICT. This contraction in results of different studies was the central motivation for conducting this study, to investigate the link between ICT and inbound tourism demand on greenhouse gas emissions in South Africa, using the ARDL model and Granger causality. The ARDL results indicate that only inbound tourism demand has a positive effect on greenhouse gas emissions in the long run. The level of greenhouse gas emissions goes up by 0.52% when foreign tourist arrivals increase by 1%. The use of ICT has an effect on greenhouse gas emissions only in the short run, where greenhouse gas emissions grow 0.61% when the use of ICT increases by 1%. Unlike in the long run, inbound tourism demand has no effect on greenhouse gas emissions in the short run. The Granger causality results, on the other hand, show a unidirectional causality relationship running from greenhouse gas emissions to ICT and inbound tourism demand. There is no causal relationship between ICT and inbound tourism demand.

The theoretical contribution of this study is the expansion of the existing literature. There are scant empirical studies investigated the relationship among three variables, which are greenhouse gas emissions, ICT, and tourism activities. Previous studies focused mainly on the relationship between two variables. Furthermore, this study differs from previous studies in terms of methodology. Paper used time series data and employed principal component analysis (PCA) to construct one single ICT index for three ICT indices (fixed telephone users, mobile cellular subscriptions, and the internet users), instead of using the traditional method of calculating the average or the total of the three indices.

The policy implication of this study is that South Africa has to promote vehemently the use of ICT in the tourism sector in attempts to mitigate the long-run effects of tourist arrivals on greenhouse gas emissions. An increase in tourist arrivals has a long-run effect on greenhouse gas emissions, but advancements in ICT have no long run effect on greenhouse gas emissions. Therefore, ICT may be used to curb an increase in greenhouse gas emissions caused by an increase in tourist arrivals.

This study was limited to greenhouse gas emissions, ICT, and inbound tourism demand, future studies may investigate the relationship among greenhouse gas emissions, ICT, and domestic tourism demand or outbound tourism demand. The study also used three indices (fixed telephone subscriptions, internet users, and mobile cellular subscribers) as proxies for ICT, future studies may include more proxies to construct one index for ICT.

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