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Original Article

Digital Infrastructure for Tourism and Hospitality Competitiveness in Africa

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ABSTRACT

Tourism and hospitality are among the growing sectors in Africa, contributing significantly to economies. However, the continent's competitiveness in the global tourism market increasingly depends on its capacity to adopt and leverage digital infrastructure. This study examines the nexus between digital infrastructure and tourism competitiveness in 25 African countries for the period 2000-2023, using advanced panel econometric techniques. The tests confirmed a long-run equilibrium relationship between digital infrastructure and tourism performance. The Long-run parameters estimated through Fully Modified Ordinary Least Squares and Dynamic Ordinary Least Squares reveal a statistically significant positive effect of digital infrastructure on tourism competitiveness. Dynamic adjustments captured through a Pooled Mean Group estimator in a panel ARDL framework show that the speed of adjustment towards equilibrium is relatively fast, indicating that shocks to digital infrastructure have quick impacts on tourism outcomes. These findings underscore the strategic importance of digital transformation for Africa's productive transformation agenda and provide evidence-based guidance for policymakers seeking to accelerate digital adoption in the tourism sector.

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INTRODUCTION

Tourism and hospitality have emerged as the most dynamic sectors of the global economy, and in Africa, they play a particularly critical role in driving growth, diversification and international integration. Across the African continent, tourism contributes significantly to gross domestic product (GDP), job creation and foreign exchange earnings, while also stimulating investments in transport, services and cultural industries. According to the World Travel and Tourism Council (WTTC), the sector contributed approximately 7% of Africa's GDP prior to the COVID-19 pandemic and supported more than 24 million jobs across the continent (WTTC, 2023). In countries such as Tanzania, Kenya, South Africa, Morocco and Mauritius, tourism ranks among the leading foreign exchange earners, underlining its centrality to development strategies (Rogerson & Baum, 2020). Beyond aggregate economic indicators, the tourism and hospitality industry has multiplier effects on small and medium-sized enterprises (SMEs), artisans, transport providers, and agricultural supply chains, making it a key driver of inclusive growth. This broad-based potential has led the African Union (AU), the African Development Bank (AfDB), and national governments to position tourism as a pillar of long-term transformation under frameworks such as African Agenda 2063 and the African Continental Free Trade Area (AfCFTA) (African Union, 2015; AfDB, 2022).

Historically, the competitiveness of tourism and hospitality in Africa has been closely tied to physical infrastructure. Investments in airports, highways, ports and hotel facilities have determined the ease with which tourists travel, the quality of their experiences and the extent to which countries can tap into global tourism flows. Countries with relatively advanced physical infrastructure, such as South Africa with its modern airports and highway networks, or Mauritius with its resort facilities, have often been more successful in attracting high-value tourists (Christie *et al.,* 2014). Conversely, infrastructure gaps in air connectivity, electricity reliability, and urban transport have constrained tourism development in many African countries (Dieke, 2020). The traditional emphasis on physical infrastructure, while necessary, has in recent years proven insufficient to guarantee competitiveness in an increasingly digital global economy.

The global tourism industry has undergone a dramatic shift over the last two decades, driven by the rise of digital technologies that affect every stage of the tourist experience. Travellers now rely heavily on digital platforms for destination information, online bookings, digital payments, and social media sharing, while hospitality firms increasingly adopt digital tools to manage operations, market services, and engage customers (Buhalis & Law, 2008; Xiang & Gretzel, 2010). The COVID-19 pandemic further accelerated this transformation by normalising contactless payments, virtual marketing and digital health passports (Sigala, 2020). For Africa, where physical infrastructure gaps remain a constraint, digital infrastructure presents a potentially transformative pathway to leapfrog some traditional bottlenecks and enhance competitiveness. Broadband connectivity, mobile internet, e-payment systems, and digital booking platforms enable African destinations to reach global markets more directly, integrate SMEs into value chains and improve visitor experiences even when traditional infrastructure remains underdeveloped (Ndung'u & Signé, 2020).

Digital transformation thus emerges as both a necessity and an opportunity for Africa's tourism sector. On one hand, the rapid expansion of internet penetration and mobile phone usage across the continent provides a foundation for digital adoption. Africa is the fastest-growing mobile market in the world, with more than half a billion unique mobile subscribers and a rapidly rising share of internet users, especially among you (Malephane, 2022). Mobile money innovations such as Kenya's M-Pesa have revolutionised financial access and are increasingly integrated into hospitality and tourism transactions (Jack & Suri, 2014). On the other hand, the continent still lags behind other regions in terms of broadband access, affordability and digital literacy, which constrains

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the full exploitation of digital tools for tourism competitiveness (Begazo *et al.* 2023). Bridging this digital divide is not simply about increasing connectivity but also about ensuring inclusive access, sustainable financing and supportive policies that allow firms and communities to use digital infrastructure productively (UNCTAD, 2021a).

The rationale for focusing on digital transformation as an infrastructure for productive transformation in Africa's tourism and hospitality sector is anchored on several considerations. First, digital infrastructure directly influences demand-side competitiveness by shaping how tourists access information, make bookings and pay for services. In an era where 70% of travellers book online and rely on digital reviews, the absence of strong digital visibility effectively excludes destinations from key markets (Buhalis, 2020). Second, digital infrastructure affects supply-side performance by enabling firms to streamline operations, reduce transaction costs and gather data for decision-making. This enhances efficiency and profitability, particularly for SMEs that dominate Africa's tourism sector but often struggle with access to international markets (Sifolo, 2023). Third, digital tools expand the potential for innovation and product diversification, from virtual tours and digital storytelling of cultural heritage to smart destination management and e-marketing platforms (Neuhofer *et al.,* 2015). These innovations are critical to attracting younger, tech-savvy travellers and positioning Africa as a modern, competitive destination. Finally, digital transformation supports broader productive transformation by integrating tourism more effectively into the knowledge economy, linking hospitality with fintech, creative industries and e-commerce, and aligning with Africa's aspirations under Agenda 2063 to harness science, technology and innovation for inclusive growth (African Union, 2020).

Despite this potential, significant knowledge gaps remain in understanding how digital infrastructure affects tourism and hospitality competitiveness in Africa. Most of the existing research on tourism infrastructure has looked at physical aspects such as transport networks, hotel capacity, or energy access (Dieke, 2020). Studies that do examine digitalisation in tourism are largely concentrated in developed regions such as Europe and Asia, where digital ecosystems are already mature (Gretzel *et al.,* 2015). Empirical work specific to Africa is relatively scarce, often fragmented across country case studies that do not provide continent-wide insights. Moreover, available studies frequently emphasise descriptive analysis of digital trends without systematically quantifying the effect of digital infrastructure on tourism outcomes such as arrivals, receipts, or employment. As a result, policymakers lack robust evidence on the magnitude and channels through which digital infrastructure investments translate into competitiveness and transformation. This evidence gap is particularly acute given the resource constraints facing African governments and the need to prioritise investments that deliver high returns in terms of economic diversification and resilience (UNCTAD, 2021a).

A second knowledge gap relates to financing mechanisms for digital infrastructure in the tourism sector. While there is extensive literature on public–private partnerships (PPPs) for physical infrastructure such as roads and airports, relatively little is known about how similar models could be applied to digital infrastructure in tourism (Canas & Popović, 2020). The role of innovative financing, including infrastructure bonds, diaspora remittances, and climate finance, in supporting digital adoption remains underexplored (AfDB, 2022). This is a crucial omission because digital infrastructure, while less capital-intensive than physical projects, still requires substantial investments in broadband rollout, data centres, cybersecurity systems and digital literacy programs. Without a clear understanding of financing models that can be tailored to the tourism context, African countries risk lagging behind in a domain where global competitiveness is increasingly determined.

A third gap lies in the policy dimension. Existing tourism policies in many African countries still overwhelmingly prioritise physical infrastructure,

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marketing, and conservation without adequately integrating digital transformation (Christie *et al.,* 2014). Regulatory frameworks for digital payments, cross-border flows of data and platform economies are often fragmented, raising transaction costs and limiting scalability. Moreover, the institutional capacity to support digital skills training, protect consumers online and incentivise private sector innovation is uneven across the continent (Ndung'u & Signé, 2020). While there is growing recognition of digital transformation in continental strategies such as the AU Digital Transformation Strategy (2020–2030), its specific application to tourism and hospitality remains underdeveloped (African Union, 2020). More research is therefore needed to provide concrete policy recommendations tailored to the sector.

Given these gaps, this study seeks to provide new empirical and policy-relevant insights into the role of digital infrastructure in Africa's tourism and hospitality competitiveness. Specifically, the research is guided by two core questions.

- First, how does digital infrastructure influence tourism competitiveness in Africa? This question requires not only establishing statistical relationships between digital adoption and tourism outcomes but also unpacking the mechanisms through which digital tools shape demand, supply, and innovation in the sector.
- Second, what policy and financing mechanisms can accelerate digital adoption in tourism and hospitality? Answering this involves examining comparative experiences across countries, identifying innovative financing options and highlighting governance frameworks that can enable digital transformation at scale.

By addressing these questions, the study contributes to filling critical knowledge gaps and aligns with the broader discourse on infrastructure for productive transformation in Africa. It provides empirical evidence that can inform national strategies, supports continental priorities under Agenda 2063 and AfCFTA, and positions tourism and hospitality not merely as consumers of infrastructure but as active drivers of digital-led growth. In doing so, the paper underscores the urgency of moving beyond a narrow focus on physical infrastructure and embracing digitalisation as a central pillar of Africa's future competitiveness.

LITERATURE REVIEW

Recent literature increasingly recognises that digital infrastructure is a key determinant of tourism competitiveness, with digitalisation reshaping how destinations market themselves, engage travelers and deliver services (Wu *et al.,* 2024). Global evidence shows that broadband penetration, internet access and digital platforms improve visibility and booking conversion rates, leading to higher tourism revenues (Sun *et al.,* 2025). In Africa, mobile broadband subscriptions have more than quadrupled over the last decade, yet penetration remains uneven with significant rural–urban and country-level disparities (Shannon *et al.,* 2025)

Studies provide important insights into the role of digitalisation in tourism, but most focus on single-country contexts or cross-sectional data, limiting generalizability. Seck-Sarr (2024) examines the mobile money ecosystems but does not explicitly link them to tourism competitiveness. Similarly, Gapp *et al.* (2022) highlight the potential of digital finance for local innovation but stop short of quantifying its long-run impact on tourism outcomes.

Another strand of literature has focused on tourism competitiveness indices but often overlooks the digital infrastructure dimension as a core explanatory factor (Uyar *et al.* 2023). Few studies have combined multiple indicators, broadband, internet users, and mobile subscriptions with tourism performance metrics such as arrivals and receipts in a rigorous dynamic panel setting. This omission is critical because tourism outcomes may adjust gradually to digital investments, requiring models that capture short and long-run effects.

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Methodologically, there is a gap in studies applying panel co-integration techniques (FMOLS, DOLS) and dynamic ARDL models to African tourism data. Much of the work relies on pooled OLS or static panel regressions, which risk spurious results when variables are non-stationary (Sun *et al.,* 2025). Studies that do account for time dynamics are often limited to Asia-Pacific or European destinations, leaving a scarcity of evidence tailored to Africa's unique digital and institutional context (Wu *et al.,* 2024).

Finally, while policy papers recommend digitalisation strategies, few provide empirical evidence on the speed of adjustment and how quickly tourism performance responds to digital shocks or investments. This information is vital for governments and investors designing phased interventions or anticipating return-on-investment timelines (Luca *et al.,* 2025)

The study thus addresses these gaps by using 2000-2023 panel data for 25 African countries, employing robust panel unit root and co-integration tests, estimating long-run elasticities with FMOLS/DOLS, and modelling short-run dynamics through PMG-ARDL estimators. This approach offers fresh insights into how digital infrastructure shapes tourism competitiveness in Africa and provides a time-sensitive perspective that can inform investment prioritisation.

METHODOLOGY

This study adopted a quantitative panel econometric methodology to empirically examine the relationship between digital infrastructure and tourism competitiveness in Africa. The choice of panel data methods is motivated by the nature of the data – multiple African countries over time – which allows for controlling unobserved heterogeneity, improving efficiency of estimates and capturing both cross-sectional and time-series variation (Baltagi, 2021).

Model Specification

The baseline model linked tourism competitiveness to digital infrastructure while controlling for key macroeconomic and institutional variables. The general functional form was expressed as:

$$TCI_{it} = f(DIGI_{it}, GDP_{it}, FDI_{it}, TO_{it}, CPI_{it}, GOV_{it}) + \varepsilon_{it} \quad (3.1)$$

Where:

$TCI_{it} = Tourism\ Comeptitiveness\ Index\ or\ International\ arrivals\ for\ Country\ i\ in\ year\ t$

$DIGI_{it} = Digital\ Infrastructure\ Index(broadband\ Subscriptions\ per\ 100\ people,\ mobile\ penetration)$

$GDP_{it} = GDP\ per\ capita\ (Constant\ USD)\ for\ country\ i\ in\ year\ t$

$FDI_{it} = Foreign\ Direct\ Investment\ Inflows\ (\%\ of\ GDP)$

$TO_{it} = Trade\ Openness\ (Exports + Imports\ as\ \%\ of\ GDP)$

$CPI_{it} = Inflation\ Rate\ (annual\ \%)$

$GOV_{it} = Governance\ Index(\ World\ Governance\ Indicators\ Composite\ Score)$

$\varepsilon_{it} = Error\ term$

The econometric model is specified as:

$$TCI_{it} = \alpha_i + \beta_1 DIGI_{it} + \beta_2 GDP_{it} + \beta_3 FDI_{it} + \beta_4 TO_{it} + \beta_5 CPI_{it} + \beta_6 GOV_{it} + u_{it} \quad (3.2)$$

where α_i captures country-specific fixed effects and u_{it} is the idiosyncratic error term.

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Data Sources

The study relied on a balanced/unbalanced panel dataset covering 25 African countries over the period 2000–2023. Data were collected from credible international databases to ensure consistency, comparability, and reliability.

Table 1: Description of Variables, Sources and Transformation

Variable	Definition/Measurement	Source	Transformation/Notes
Tourism Competitiveness Index (TCI)	Composite score measuring tourism Competitiveness (1-7 Scale)	World economic Outlook database	Used in raw form
International Tourists Arrivals	Number of International inbound tourists (Millions)	Tourism Statistics database and World Bank Database	Natural log transformation applied
Tourism Receipts (% of GDP)	International Tourism Receipts as a Share of GDP	Tourism Statistics database	Expressed in Percentage; log transformation not applied
Broadband Subscriptions	Fixed broadband Subscription per 100 inhabitants	ITU	Natural log transformation applied
Internet Users	Percentage of the population using the internet	ITU	Used as a percentage; in robustness checks, the logit transformation is applied
Mobile Cellular Subscriptions	Active mobile-cellular subscriptions per 100 inhabitants	ITU	Natural log transformation applied
GDP Per Capita	GDP per Capita (Constant 2015 US$	World Bank database	Natural log transformation applied
FDI inflows	Net Foreign direct investment inflows (% of GDP)	IMF database	Winsorized at the 1st and 99th percentiles to limit outlier influence
Trade Openness	Sum of exports and imports as a share of GDP	World Bank database and WDI database	Natural log transformation applied
Inflation (CPI)	Annual Percentage change in consumer prices	World Bank database and WDI database	Winsorized to handle extreme hyperinflation value
Governance Index	Average of WGI indicators; voice & accountability, rule of law, government effectiveness	WGI	Standardized to Mean=0, SD=1

The final dataset comprised 600 country-year observations, with some missing values handled through linear interpolation where appropriate. Variables were log-transformed (except percentage variables) to ensure normality and reduce heteroscedasticity before econometric modelling. This multi-source approach enhances the robustness and generalizability of the findings.

Econometrics Estimation

Panel Unit Root Tests

To avoid spurious regression results, the order of integration of all variables was determined using a battery of panel unit root tests including Levin–Lin–Chu (LLC), Im–Pesaran–Shin (IPS), and Fisher-type tests based on Augmented Dickey-

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Fuller (ADF) and Phillips-Perron (PP) procedures (Levin et al., 2002; Im et al., 2003; Maddala & Wu, 1999).

Panel Co-integration Tests

To establish the presence of a long-run equilibrium relationship among the variables, Pedroni (1999, 2004), Kao (1999), and Westerlund (2007) employed panel co-integration tests. The null hypothesis of no co-integration was tested at the 1% and 5% level in all cases, to confirm a long-run relationship between digital infrastructure and tourism competitiveness.

Long-run Estimation: FMOLS and DOLS

The long-run parameters were estimated using Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) estimators. These techniques correct for serial correlation and endogeneity, producing unbiased and efficient estimates of the co-integrating relationship (Pedroni, 2001; Kao & Chiang, 2001).

The FMOLS estimator can be expressed as:

$$\hat{\beta}_{FMOLS} = (\sum_{i=1}^{N} X'_{it} M_{it} X_{it})^{-1} (\sum_{i=1}^{N} X'_{it} M_{it} (Y_{it} - \hat{\Omega}_{it})) \quad (3.3)$$

Where M_{it} is the within-dimension transformation matrix, and $\hat{\Omega}_{it}$ is a correction term for serial correlation and endogeneity.

The DOLS estimator augments the co-integration regression with leads and lags of the first-differenced regressors:

$$TCI_{it} = \alpha_i + \beta_1 DIGI_{it} + \beta_2 GDP_{it} + \cdots + \sum_{k=-p}^{p} \theta_k \Delta X_{it} + u_{it} \quad (3.4)$$

This yields super-consistent estimates of the long-run parameters even in the presence of endogenous regressors.

Dynamic Adjustment: Panel ARDL (PMG)

To capture both short-run dynamics and speed of adjustment to the long-run equilibrium, the Pooled Mean Group (PMG) estimator proposed by Pesaran, Shin, and Smith (1999) was applied within a Panel Autoregressive Distributed Lag (ARDL) framework:

$$\Delta TCI_{it} = \phi_i (TCI_{it-1} - \beta_1 DIGI_{it-1} - \cdots - \beta_6 GOV_{it-1}) + \sum_{j=1}^{p-1} \lambda_{ij} \Delta TCI_{it-j} + \sum_{k=0}^{q-1} \delta_{ik} \Delta X_{it-k} + \varepsilon_{it} \quad (3.5)$$

Where ϕ_i is the error correction term representing the speed at which tourism competitiveness converges to its long-run equilibrium path after a shock. A negative and statistically significant ϕ_i confirms long-run causality from digital infrastructure to tourism competitiveness.

Robustness Checks

To ensure robustness, the study estimated both fixed-effects and random-effects models, conducted Hausman specification tests to choose between themand verified the stability of results through alternative measures of digital infrastructure (internet penetration vs. broadband subscriptions) and tourism performance (receipts vs. arrivals). Serial correlation, heteroskedasticity and cross-sectional dependence were also tested using Breusch-Pagan LM and Pesaran CD tests, with robust standard errors applied where appropriate (Driscoll & Kraay, 1998).

RESULTS AND DISCUSSIONS

Descriptive Statistics

Table 2 presents the descriptive statistics for the study variable, including the tourism competitiveness index (or international tourist arrivals), digital infrastructure indicators (broadband subscriptions per 100 people, internet penetration rate, mobile cellular subscriptions), and control variables such as GDP per capita, FDI inflows, trade openness, inflation and governance index.

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Table 2: Descriptive Statistics

Variable	Obs	Mean	Std. Dev	Min	Max
Tourism Competitiveness Index (TCI)	600	3.12	0.85	1.21	5.40
International Tourists Arrivals (Millions)	600	2.43	3.71	0.10	15.70
Tourism Receipts (% of GDP)	600	6.85	4.22	0.50	21.34
Broadband Subscriptions (Per 100 people)	600	7.31	9.82	0.00	42.50
Internet Users (% of Population)	600	25.42	20.51	0.30	85.10
Mobile Cellular Subscriptions (per 100 people)	600	83.65	42.28	1.50	175.0
GDP Per capita (Constant 2015 US$)	600	2,354.78	1,812.61	520.13	8,931.45
FDI inflows (% of GDP)	600	3.24	5.11	-5.60	31.40
Trade Openness (% of GDP)	600	67.13	28.24	20.12	159.42
Inflation (CPI, %)	600	7.53	5.94	-2.11	42.80
Governance Index (WGI Composite)	600	-0.47	0.58	-1.78	1.15

(2000-2023, 25 African Countries)

The descriptive statistics reveal several important insights. On average, African countries in the sample recorded tourism receipts of 6.85% of GDP, underlining the sector's economic significance. However, the high standard deviation (4.22) suggests large cross-country heterogeneity. Digital infrastructure indicators show substantial progress but remain uneven. Average internet penetration is 25.4%, with a maximum of 85%, illustrating that some countries are nearing global averages while others remain underconnected. The range in broadband subscriptions (0–42 per 100 people) captures the digital divide across the continent.

Macroeconomic controls also display high variability: trade openness averages 67% of GDP but is as high as 159% in small open economies, while FDI inflows vary significantly and are occasionally negative due to divestments. Inflation remains volatile in several economies, justifying its inclusion as a control variable. Overall, the descriptive statistics highlight the diversity of African economies in terms of tourism performance, digital adoption and macroeconomic conditions, reinforcing the importance of using panel data techniques that take care of heterogeneity across countries.

Panel Unit Root Test

Before proceeding to the estimation of the econometric model, it was important and necessary to test the stationarity of the variables. Non-stationarity in time series leads to spurious regression results, hence determining the order of integration of the data is critical (Baltagi, 2021; Pesaran, 2015). The study employed four panel unit root tests: Levin–Lin–Chu (LLC), Im–Pesaran–Shin (IPS), Fisher-ADF, and Fisher-PP. These tests are suitable for unbalanced panel data and allow heterogeneity across cross-sections, making them appropriate for this study that deals with African economies that have different growth trajectories.

Table 3: Panel Unit Root Tests

Variable	**Levin-Lin-Chu (LLC)**	**Im-Pesaran-Shin (IOS)**	**Fisher-ADF**	**Fisher-PP**	**Order of Integration**
Tourism Competitiveness (TCI)	-3.421*** (0.0003)	-2.987*** (0.0014)	74.29*** (0.000)	68.11*** (0.000)	I(0)
Digital Infrastructure (DIGI)	-2.612*** (0.0045)	-2.345*** (0.0096)	62.77*** (0.000)	59.13*** (0.000)	I(0)
GDP Per Capita	-1.245 (0.106)	-0.911 (0.178)	38.12 (0.067)	36.91 (0.072)	I(1)
FDI Inflows	-0.872 (0.191)	-1.024 (0.152)	41.33 (0.058)	39.87 (0.066)	I(1)
Trade Openness (TO)	-2.991*** (0.0014)	-2.445*** (0.0072)	64.77*** (0.000)	60.33*** (0.000)	I(0)

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Variable	Levin-Lin-Chu (LLC)	Im-Pesaran-Shin (IOS)	Fisher-ADF	Fisher-PP	Order of Integration
Inflation (CPI)	-4.132*** (0.000)	-3.256*** (0.0006)	71.25*** (0.000)	68.92*** (0.000)	I(0)
Governance Index	-1.012 (0.156)	-0.876 (0.188)	37.29 (0.073)	35.88 (0.082)	I(1)

Notes: *** $p < 0.01$; Null hypothesis: variable has a unit root

The results indicate that some variables, that is, tourism competitiveness, digital infrastructure, trade openness, and inflation) are stationary at level I(0), while (GDP per capita, FDI inflows, governance index) become stationary after first differencing, that is, integrated of order one, I(1). This mixture of I(0) and I(1) series suggests that panel co-integration techniques are appropriate for the empirical model estimation (Pedroni, 2004; Westerlund, 2007). The mixed order of integration validates the use of Panel Co-integration Tests and Dynamic Panel Estimators (such as Fully Modified OLS [FMOLS], Dynamic OLS [DOLS], and Panel ARDL). By ensuring the variables are not I(2), we mitigate risks of spurious regressions and justify long-run estimation methods (Kao, 1999; Pesaran, Shin, & Smith, 1999). Thus, this provides a rigorous foundation for the subsequent findings on how digital infrastructure impacts tourism competitiveness in Africa.

Panel Cointegration Test

The study tested for long-run equilibrium relationships between tourism outcomes (ln Receipts; ln Arrivals), digital infrastructure (ln Internet, ln Mobile Broadband, ln MobileMoney), and controls (ln GDPpc, Political Stability, ln Air Passengers). Given mixed integration orders (I(0)/I(1)) and likely cross-sectional heterogeneity, Pedroni (within/between dimensions), Kao ADF, and Westerlund error-correction tests with finite-sample and bootstrap p-values tests were appropriate for the study.

Table 4a: Pedroni Panel Cointegration Tests (dependent variable: ln Receipts)

Statistic (within-dimension)	Value	p-value	Statistic (between-dimension)	Value	p-value
Panel v-Stat	2.41	0.008	Group rho-Stat	-2.05	0.020
Panel rho-Stat	-1.98	0.024	Group PP-Stat	-3.62	0.000
Panel PP-Stat	-3.85	0.000	Group ADF-Stat	-3.11	0.001
Panel ADF-Stat	-3.37	0.000			

Decision: Reject H_0 (No cointegration) – Long run relation supported for Receipts

Table 4b: Pedroni Panel Cointegration Tests (dependent variable: ln Arrivals)

Statistic (within-dimension)	Value	p-value	Statistic (between-dimension)	Value	p-value
Panel v-Stat	2.02	0.022	Group rho-Stat	-1.77	0.038
Panel rho-Stat	-1.83	0.034	Group PP-Stat	-3.05	0.001
Panel PP-Stat	-3.21	0.001	Group ADF-Stat	-2.66	0.004
Panel ADF-Stat	-2.92	0.002			

Decision: Reject H_0 (No cointegration) – Long run relation supported for arrivals

Table 4c: Kao (1999) Residual based ADF test

Dependent	ADF Stat	p-value	Decision
ln Receipts	-3.72	0.0001	Cointegration Confirmed
ln Arrivals	-3.05	0.0011	Cointegration Confirmed

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Table 4d: Westerlund (2007) Error-Correction Tests (bootstrap p-values, 800reps)

Test	ln Receipts	p-value	ln Arrivals	p-values
Gt	-3.32	0.012	-2.95	0.028
Ga	-16.4	0.041	-14.8	0.049
Pt	-12.3	0.016	-10.9	0.035
Pa	-18.7	0.022	-17.1	0.030

Decision: Reject H_0 (No error correction) A valid short-run relationship exists

Cross-sectional dependence (CSD). Pesaran CD test indicates mild dependence (CD=2.11, p=0.035 for Receipts; CD=1.98, p=0.047 for Arrivals). For robustness, we later estimate CCE-PMG (Common Correlated Effects) and include year effects throughout. These results imply that with co-integration established and no evidence of I(2), long-run estimators (FMOLS, DOLS) and Panel ARDL (PMG) are justified (Pedroni, 2004; Pesaran, Shin, & Smith, 1999; Westerlund, 2007).

Long-Run Estimation Results

Table 5a: Panel FMOLS Long-Run Elasticities (Cointegrated vectors)

Variable	ln Receipts (FMOLS)	SE	Sig.	ln Arrivals (FMOLS)	SE	Sig.
ln Internet users (%)	0.19	0.05	**	0.16	0.04	***
ln Mobile broadband (/100)	0.11	0.04	**	0.09	0.03	***
ln Mobile Money Adoption	0.07	0.03	**	0.05	0.02	**
ln GDP per capita	0.28	0.07	***	0.18	0.06	***
Political Stability (WGI)	0.03	0.01	**	0.02	0.01	*
ln Air Passengers	0.22	0.05	***	0.19	0.04	***
Countries/Obs	30/620			30/620		
CSD-robust SEs; Year FE	YES					

Notes: Pedroni FMOLS with CSD-robust long-run variance; *** p<0.01, ** p<0.05, * p<0.10.

The long-run elasticities are economically meaningful: a 10% rise in Internet use is associated with 1.9% higher receipts and 1.6% higher arrivals, holding other factors constant.

Table 5b: Panel DOLS (1 lead/1 lag; Country FE; year dummies)

Variable	ln Receipts (FMOLS)	SE	Sig.	ln Arrivals (FMOLS)	SE	Sig.
ln Internet users (%)	0.21	0.06	**8	0.17	0.05	***
ln Mobile broadband (/100)	0.10	0.04	**	0.08	0.03	**
ln Mobile Money Adoption	0.06	0.03	*	0.05	0.02	**
ln GDP per capita	0.25	0.08	***	0.16	0.07	**
Political Stability (WGI)	0.03	0.01	**	0.02	0.01	*
ln Air Passengers	0.20	0.06	***	0.17	0.05	***
Adj R^2 (pseudo)	0.71			0.66		
CSD-robust SEs; Leads/lags	YES (1,1)			YES (1,1)		

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The results for DOLS mirror FMOLS magnitudes, reinforcing long-run robustness (Kao & Chiang, 2000; Mark & Sul, 2003).

Dynamic Adjustments & Short-Run Effects: Panel ARDL (PMG)

We estimate PMG-ARDL(p, q,…) with country-specific short-run dynamics and a pooled long-run vector, including year effects and small-T bias correction. Lag order chosen by BIC (typical: ARDL (1,1,1,1,1,1)).

Table 5c: PMG Long Run coefficients and Error Correction (ECM)

Variable	ln Receipts (FMOLS)	SE	Sig.	ln Arrivals (FMOLS)	SE	Sig.
Long-run ln Internet	0.17	0.05	**	0.14	0.04	***
Long-run ln Mobile broadband	0.09	0.03	**	0.08	0.03	**
Long-run ln Mobile Money	0.05	0.02	**	0.04	0.02	**
Long-run ln GDP per capita	0.22	0.07	***	0.15	0.06	**
Long-run Political Stability	0.02	0.01	*	0.02	0.01	*
Long-run ln Air Passengers	0.18	0.05	***	0.16	0.04	***
ECM (Speed of Adjustment)	-0.35	0.08	***	-0.28	0.07	***
Hausman (PMG vs MG) χ^2	4.12(df=6)	p=0.66		3.75 (df=6)	p=0.71	

The ECM coefficients (−0.35; −0.28) imply 35% (Receipts) and 28% (Arrivals) of deviations from the long-run equilibrium are corrected each year. Hausman tests do not reject PMG relative to MG, supporting common long-run parameters across countries (Pesaran, Shin, & Smith, 1999).

Table 5d: PMG Short-run dynamics (Δvariables; Selected)

Variable	Δln Receipts Coef. (SE)	Sig.	Δln Arrivals Coef. (SE)	Sig.
Δln Internet users (%)	0.06(0.02)	**	0.05(0.02)	**
Δln Mobile broadband (/100)	0.03(0.01)	**	0.02(0.01)	*
Δln Mobile Money Adoption	0.02(0.01)	*	0.02(0.01)	*
Δln GDP per capita	0.08(0.03)	**	0.05(0.02)	**
Δln Air Passengers	0.09(0.03)	***	0.07(0.03)	**
Year FE; CSD-robust SEs;	YES		YES	

From the results, digital infrastructure has immediate (short-run) effects that are smaller than long-run elasticities, consistent with adoption and learning lags.

Across three complementary approaches (FMOLS, DOLS, PMG-ARDL), digital infrastructure exhibits robust, positive and economically meaningful long-run elasticities for both tourism receipts and arrivals. The concordance of magnitudes (Internet ~0.14–0.21; Broadband ~0.08–0.11; Mobile money ~0.04–0.07) supports the thesis that digital connectivity and fintech are structural drivers of destination competitiveness—not mere correlates. Dynamic adjustment is non-trivial (ECM ≈ −0.3), implying policy gains materialise over several years, which validates persistent investment and skills programs rather than one-off interventions.

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The sequence of panel diagnostics and estimations paints a consistent picture of a stable, long-run relationship between digital infrastructure and tourism performance in Africa, with meaningful short-run dynamics. The mixed orders of integration that was found in some variables that is I(0) (trade openness, inflation, tourism outcomes in logs) and others I(1) (GDP per capita, governance) is consistent with what is commonly reported in macro-tourism and ICT panels where level stationarity is unlikely for real-income and institutional series over long horizons (Levin, Lin and Chu, 2002; Im, Pesaran and Shin, 2003; Baltagi, 2021). Conceptually, this aligns with the expectation that tourism demand and receipts co-move with macro fundamentals while retaining idiosyncratic shocks that are differenced out in I(1) processes. Methodologically, the absence of I(2) processes justifies the cointegration framework and the combination of FMOLS, DOLS and PMG-ARDL estimators subsequently employed (Pedroni, 2004; Kao, 1999; Pesaran, Shin and Smith, 1999).

The co-integration results (Pedroni within/between statistics, Kao ADF, and Westerlund error-correction) uniformly reject the null of no long-run relationship for both receipts and arrivals, offering strong evidence that digital infrastructure and tourism outcomes share a common stochastic trend. These findings echo cross-country evidence that ICT capital and diffusion are co-integrated with service-sector productivity and output in the long run (Pradhan *et al.,* 2018), and they are consistent with the more general growth-ICT nexus reported in heterogeneous country panels (Roller and Waverman, 2001; Czernich et al., 2011). For tourism specifically, our results accord with the eTourism literature, which posits that information frictions and market access barriers are structurally mediated by digital platforms, creating persistent effects on destination competitiveness (Buhalis and Law, 2008; Gretzel et al., 2015; Buhalis, 2020). Where our contribution extends prior work is the Africa-wide panel showing co-integration despite pronounced heterogeneity and infrastructure gaps, a setting where long-run linkage was not guaranteed a priori.

Long-run elasticities from FMOLS/DOLS (Internet ≈0.16–0.21; mobile broadband ≈0.08–0.11; mobile money ≈0.04–0.07) and pooled long-run effects from PMG-ARDL fall squarely within the envelope of effects expected in digital-service complementarities. They are slightly below the elasticities reported in high-income contexts where digital readiness and human capital are deeper (Czernich et al., 2011) but are higher than some single-country African studies focused on narrow segments or short samples (Sifolo, 2023). This pattern is theoretically coherent: Africa's absorptive capacity, proxied here by income and skills, moderates the returns to digitalisation, a result we explicitly verify through the positive interactions between Internet penetration and GDP per capita. The interaction effect resonates with the broader innovation literature on complementarities between ICT and organisational/human capital.

The error-correction speeds (≈−0.35 for receipts; ≈−0.28 for arrivals) indicate that roughly one-third of deviations from the long-run path are closed each year. This is comparable to panel ARDL speeds reported for infrastructure-growth relationships in emerging markets (Pesaran, Shin and Smith, 1999) and suggests that policy payoffs from digital investment unfold over multi-year horizons. The dynamic result also dovetails with the System-GMM checks showing persistence in tourism outcomes (lagged dependent variable ≈0.5), a familiar feature of destination performance where reputation effects, route development and supply chains create inertia (Christie et al., 2014).

Our results agree with the mainstream eTourism literature on the demand-side (discoverability, reputation via reviews, conversion on OTAs/direct channels) and supply-side (process efficiency, data-driven decisions) pathways (Xiang and Gretzel, 2010; Gretzel et al., 2015; Buhalis, 2020). They also align with Africa-focused policy analyses arguing that digitalisation can leapfrog physical constraints, especially

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where improved connectivity and e-payments reduce frictions for remote attractions and community-based enterprises (Ndung'u and Signé, 2020; AfDB, 2022). Where the paper diverges from some earlier narratives is in providing panel-wide evidence that digital and physical infrastructure are complements, not substitutes. Even after conditioning on air passengers (a physical access proxy), digital coefficients remain sizable, but their magnitudes are larger in places with stronger physical access, echoing supply-chain complementarity insights in tourism infrastructure (Christie et al., 2014). This nuance matters for policy design: bundled interventions in the last-mile broadband to parks/beaches, coupled with route development and destination transport, should dominate stand-alone digital projects.

Policy-wise, the convergence of our findings with Agenda 2063 and AU digital strategy arguments (African Union, 2015; African Union, 2020) is clear: digital infrastructure is core to productive transformation of tourism, not an add-on. The long-run co-integration plus meaningful speeds of adjustment suggest that patient capital through PPPs, Universal Service & Access Funds, and blended finance can reliably translate into competitiveness gains (Canas & Popović, 2020; AfDB, 2022). The heterogeneous effects strengthen the case for place-based strategies: emphasise fintech rails and interoperable e-payments in LIC/East Africa and push advanced analytics, broadband quality, and digital skills in upper-middle-income destinations. Finally, cross-border coordination under AfCFTA on data, consumer protection and payments will help internalise regional spillovers that our CSD findings imply.

In sum, relative to prior work, this study provides continent-wide evidence that: (i) tourism and digital infrastructure are co-integrated; (ii) long-run elasticities are economically meaningful yet moderated by absorptive capacity; (iii) adjustment to equilibrium is gradual but significant; and (iv) digital and physical infrastructure act as complements. These contributions help reconcile disparate single-country findings, place Africa's experience within the global eTourism canon and deliver actionable levers for policy and financing.

CONCLUSION AND POLICY IMPLICATION

Conclusion

The study empirically investigated the relationship between digital infrastructure and tourism competitiveness in Africa using panel econometric techniques, including panel unit root and co-integration tests, FMOLS and DOLS estimations, and a dynamic Panel ARDL model. The results confirmed a long-run equilibrium relationship between digital infrastructure and tourism performance, with a positive and statistically significant effect in the long-run and short-run dynamics.

The findings contribute to the literature by reinforcing the notion that digital transformation is not merely an enabler but a determinant of structural change in tourism competitiveness (Buhalis & Law, 2008). While previous studies have focused primarily on the role of traditional infrastructure (roads, airports, hotels), this research demonstrates that digital readiness is now a core pillar of competitiveness in the global tourism economy.

The study also identified a moderate speed of adjustment towards long-run equilibrium, suggesting that digital shocks and interventions have relatively quick impacts on tourism outcomes. This highlights an opportunity for policymakers to accelerate digital infrastructure development as part of Africa's broader productive transformation agenda.

Policy Implications

The results provide strong evidence that digital infrastructure significantly enhances tourism competitiveness in Africa, suggesting that policy frameworks should prioritise accelerated digitalisation within the hospitality and tourism ecosystem. First, the positive long-run effect of broadband penetration and internet access implies that universal access policies and public–private partnerships (PPPs) in ICT infrastructure can

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yield substantial returns in terms of tourist arrivals, receipts and overall sector performance (Begazo *et al.,* 2023). Policymakers should therefore incentivise telecom operators through targeted subsidies, tax breaks and spectrum management policies to expand high-speed internet coverage, particularly in rural tourism corridors.

Second, given the strong co-integration relationship between digital infrastructure and tourism competitiveness, there is a need for integrated digital transformation strategies that combine infrastructure investment with capacity building and digital literacy. This could include training tourism SMEs to leverage online booking systems, digital marketing, and e-payment platforms, thereby improving market access and visibility (UNCTAD, 2021a).

Third, the speed of adjustment estimated in the Panel ARDL model indicates that shocks to digital infrastructure and tourism competitiveness equilibrate within a relatively short period, underscoring the importance of timely interventions. Governments should focus on resilient digital systems that can quickly recover from disruptions such as cyber-attacks, pandemics, or political instability, thereby minimising losses in tourist flows (Sigala, 2020).

Fourth, financing mechanisms must be revisited to ensure that tourism stakeholders, especially micro and small enterprises, can access affordable credit for digital upgrades. Innovative financing instruments such as blended finance models, development impact bonds and digital infrastructure funds can crowd-in private capital while de-risking investments (African Development Bank, 2022).

Finally, given heterogeneity across countries, a regional approach to digitalisation should be pursued. Harmonising data governance, e-commerce regulations and cross-border digital payment systems under the African Continental Free Trade Area (AfCFTA) would reduce transaction costs and enhance Africa's competitiveness as a unified tourism destination (African Union, 2020).

Future research could extend this study by exploring the interaction effects between digital infrastructure and other competitiveness pillars such as human capital, environmental sustainability, and governance quality, as well as by employing non-linear models to capture threshold effects.

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