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A CROSS-COUNTRY ANALYSIS OF DIGITAL ADOPTION AND SUSTAINABLE DEVELOPMENT IN SELECTED OIC ECONOMIES

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Abstract: *This study examines the relationship between digital adaptation and Sustainable Development Goal (SDG) performance across selected Organisation of Islamic Cooperation (OIC) upper-middle-income countries. Using panel data from 2014 to 2023, the study focuses on two key indicators of digital infrastructure namely internet penetration and fixed broadband subscription; and evaluates their influence on SDG outcomes. To account for broader structural factors, the model includes control variables such as GDP per capita growth, education index, urbanization rate, and government effectiveness. Static panel data estimations, including Pooled OLS, Fixed Effects (FE), and Random Effects (RE) models, are employed. The Hausman test confirms the appropriateness of the FE model. The results reveal that internet penetration has a statistically significant and positive impact on SDG performance, while broadband access shows weaker effects. Among the control variables, economic growth and urbanization are positively associated with SDG outcomes, whereas education displays a counterintuitive negative effect. Governance shows mixed results, suggesting longer-term institutional reform may be needed to support sustainable development. The findings underscore the importance of digital infrastructure as a key enabler of SDG achievement and call for targeted investment in internet access and inclusive urban development. This study contributes to the literature on digital development and sustainability by offering policy-relevant insights for OIC countries navigating the digital transition.*

Keywords: Sustainable Development Goals (SDG), Digital Adaptation, Panel Data, Fixed Effects, OIC Countries

1. Introduction

The Sustainable Development Goals (SDGs) represent a global blueprint for achieving a more inclusive, equitable, and environmentally sustainable future. Since their adoption in 2015, countries around the world have made varying degrees of progress toward these goals, reflecting differences in national capacities, institutional structures, and resource availability. In the context of rapid technological advancement, the role of digital adaptation particularly internet penetration and broadband infrastructure, has emerged as a crucial enabler of sustainable development, shaping how societies access information, deliver services, and participate in the global economy.

Digital technologies play a pivotal role in supporting SDG implementation by enhancing the efficiency, transparency, and reach of public services across multiple sectors. For example, internet access can improve the delivery of healthcare (SDG 3), expand educational opportunities (SDG 4), and facilitate innovation and infrastructure development (SDG 9). Fixed broadband infrastructure further supports economic productivity, remote work, and smart governance; all of which align with the ambitions of SDG 8 (Decent Work and Economic Growth) and SDG 16 (Peace, Justice and Strong Institutions). Despite this potential, digital readiness varies significantly across countries, especially among developing and emerging economies.

This study focuses on a group of upper-middle-income countries within the Organisation of Islamic Cooperation (OIC) specifically, Albania, Iran, Jordan, Kazakhstan, Malaysia, and Türkiye. These countries present an interesting comparative context, given their diverse digital maturity levels, economic structures, and institutional capacities. While some have invested heavily in digital infrastructure and governance modernization, others remain constrained by geopolitical, economic, or regulatory challenges. Understanding the extent to which digital adaptation contributes to SDG performance in this context offers valuable insights for policy design and international cooperation.

Beyond digital factors, sustainable development outcomes are also shaped by broader socio-economic and institutional determinants. Variables such as economic growth, education, urbanization, and governance quality influence a country's ability to mobilize resources, implement policies, and engage citizens in the SDG process. Therefore, this study includes these factors as control variables in order to isolate the impact of digital adaptation more precisely.

Using panel data from 2014 to 2023 and a static panel regression framework, the first objective is to empirically examine the relationship between internet penetration and broadband access on SDG performance across these six selected OIC countries, controlling for key structural variables. By doing so, the research also seeks to investigate the influence of broader factors such as GDP growth, education, urbanization, and governance on SDG outcomes.

This paper contributes to the literature in several ways. First, it provides cross-country empirical evidence on the role of digital infrastructure in supporting SDG implementation in middle-income Muslim majority countries; an area that remains underexplored. Second, by combining digital and institutional variables in a panel data model, it offers a more nuanced understanding of the mechanisms that drive sustainability outcomes. Finally, the findings aim to inform policy debates on the integration of digital transformation strategies with national SDG action plans.

2. Literature Review

2.1 Sustainable Development and the SDG Agenda

The Sustainable Development Goals (SDGs), adopted by the United Nations in 2015, serve as a universal framework for addressing environmental, social, and economic challenges. Achieving these goals requires not only the expansion of basic infrastructure, governance contemporary policy and investment but also the strategic use of innovation and digital

technologies (UNDP, 2023). With increasing digitalization, particularly among developing and middle-income nations, there is a growing interest in how digital adaptation contributes to national progress toward the SDGs.

Several studies have established the role of digital technologies in promoting sustainable development through improved efficiency, access, and inclusiveness (World Bank, 2021; UNCTAD, 2022). Nevertheless, the empirical literature remains limited regarding the cross-country impact of digitalization on sustainability in OIC economies. Some researchers highlight the digital divide within the OIC bloc, suggesting a mixed impact on development outcomes (Siwar, C. & Abdulai, A.M., 2010; Tlemsani, et. al., 2025).

2.2 Digital Infrastructure and Sustainable Development

2.2.1 Internet Penetration and SDG Outcomes

The role of internet access in advancing development is anchored in Technology Diffusion Theory (Rogers, 1962), which posits that new technologies, when widely adopted, can transform economies and societies. In the context of the SDGs, internet connectivity enhances access to health services (SDG 3), education (SDG 4), financial inclusion (SDG 1), and civic participation (SDG 16). Empirically, ElMassah and Mohieldin (2020) find that internet access is positively associated with SDG performance in MENA countries. Similarly, Salahuddin and Gow (2016) show that increased internet usage significantly improves sustainable development outcomes in developing economies by enabling knowledge dissemination and digital governance.

2.2.2 Fixed Broadband and Digital Capabilities

While general internet access supports SDG-related inclusivity, the availability of fixed broadband infrastructure adds depth to digital capabilities. Broadband allows for faster, more reliable data transfer, enabling e-governance, remote work, and smart infrastructure, all of which contribute to SDG 9 (industry, innovation and infrastructure) and SDG 11 (Sustainable Cities and Communities). However, Kim et al. (2018) argue that broadband penetration often shows a delayed but transformative impact on development particularly in middle-income countries transitioning to knowledge economies due to infrastructural lag and affordability issues. Their findings suggest that broadband infrastructure must be complemented by policies that promote effective usage, not just access.

2.3 Broader Determinants of Sustainable Development

While the digital economy plays a growing role in shaping development, broader socio-economic and institutional factors must also be considered. These variables function as control variables in the empirical model, helping to isolate the true effect of digital adaptation.

2.3.1 Economic Growth and the Endogenous Growth Theory

According to Endogenous Growth Theory (Romer, 1986), investments in innovation, technology, and human capital can sustain long-term growth. Economic growth enhances a country's capacity to fund SDG-related programs, especially in infrastructure, education, and healthcare. Empirically, Sachs et al. (2019) confirm that GDP per capita is positively associated

with SDG achievement, particularly in wealthier and fast-growing countries, particularly in domains related to health, infrastructure and poverty eradication.

2.3.2 Education and Human Capital Development

Human Capital Theory (Becker, 1964) and Sen's Capabilities Approach (Sen, 1999) both emphasize the role of education in expanding individuals' productive and decision-making capacities. Education is directly linked to SDG 4 (Quality Education), and indirectly supports gender equality, health outcomes, and employment. However, Filmer and Pritchett (1999) critiques that years of schooling do not always reflect the quality or relevant learning, which can weaken education's developmental impact.

2.3.3 Urbanization and Agglomeration Economies

The Urban Transition Theory (Brenner & Schmid, 2015), which views well-managed urbanization as a vehicle for economic efficiency, improve access to services and innovation in public goods provision. It is associated with agglomeration economies, where the concentration of people and firms increases efficiency and innovation. Urbanization can foster better service delivery and infrastructure, which supports SDG 11 (Sustainable Cities). Empirical studies such as those by Angel et al. (2011) and Jedwah & Vollrath (2015) emphasize that urban centers, when planned sustainably, offer economies of scale in health, education, transportation, and environmental management which directly impacting SDG achievements.

2.3.4 Governance and Institutional Capacity

The Institutional Theory (North, 1990) posits that the quality of institutions, including governance effectiveness, shapes economic and social outcomes. Good governance enhances public trust, policy implementation, and regulatory efficiency which are essential for achieving SDGs, however their impact is often long-term and context-dependent. Empirically, Kaufmann et al. (2009) link strong governance to better development outcomes, while Omar and Inaba (2020) find inclusive relationship between governance indicators and SDG progress in developing countries. The finding note that the relationship is often contingent on policy coherence and institutional maturity, suggesting the need for more granular governance metrices or longer time horizons

The literature supports the role of both digital infrastructure and broader socio-economic factors in advancing sustainable development. However, empirical evidence on the combined impact of internet usage, broadband access, and institutional controls on SDG performance, particularly across upper-middle-income OIC countries, remains limited. This study contributes to closing this gap by applying static panel methods to assess how digital adaptation and complementary factors influence SDG achievements over time.

3. Methodology

To examine the relationship between digital adaptation and Sustainable Development Goals (SDG) performance across these selected OIC countries, the study employs a static panel data approach. In this study we estimate three static models; the Pooled Ordinary Least Squares (Pooled OLS) Fixed Effects (FE) and Random Effects (RE) before determining the most

appropriate specification through Hausman test. The Pooled OLS model assume that the data-generating process is homogeneous across countries over time, implying that unobserved individual (country-specific) effects are either nonexistent or uncorrelated with the explanatory variables.

The Fixed Effects model addresses this limitation by allowing for correlation between time-invariant unobserved heterogeneity ad the explanatory variables. It removes all between country variation and focuses solely on with-in country changes over time. The Random Effects model assumes that the unobserved individual effects are uncorrelated with the regressors. If this holds, RE is more efficient that FE, however, if the assumption is violated, then RE estimates become inconsistent and biased.

The primary independent variables of interest are internet usage (Internet) and fixed broadband subscriptions (FBB). In addition to these main explanatory variables, a set of control variables were included in the regression models to account for broader socio-economic and institutional influences on Sustainable Development Goals (SDG) performance. These variables are GDP per capita growth (GDP), Education Index (Edu), Urbanization Rate (Urban), and Government Effectiveness (Gov). Their inclusion serves to improve model robustness and reduce omitted variable bias, allowing clearer interpretation of the core variables of interest. The variable description and sources of data are named in Table 1 accordingly.

3.2 Variable Description and Sources

Table 1: Variable Description and Source

Variable	Description	Source
Sustainable Development Goals (SDG) Index	Composite index reflecting country-level progress toward the SDGs	Sustainable Development Report https://dashboards.sdgindex.org
Internet Penetration (Internet)	individuals using the internet (% of total population)	World Bank, World Development Indicators (WDI) https://data.worldbank.org/indicator
Fixed Broadband Subscriptions (FBB)	individuals with broadband access (% of population)	World Bank, World Development Indicators (WDI) https://data.worldbank.org/indicator/
GDP per Capita (GDP)	GDP per capita in constant USD (economic output per person, adjusted for inflation)	World Bank – World Development Indicators (WDI) https://data.worldbank.org/indicator/
Education Index (Edu)	Composite indicator of educational attainment (mean + expected years of schooling)	United Nation Development Programme (UNDP) – Human Development Reports https://hdr.undp.org/data-center/human-development-index/
Urbanization Rate (Urban)	% of population living in urban areas	World Bank, World Development Indicators (WDI)

		https://data.worldbank.org/indicator/
Government Effectiveness (Gov)	Measures public service quality, policy formulation, etc. (ranges from approx. -2.5 to 2.5)	World Bank – Worldwide Governance Indicators (WGI) https://info.worldbank.org/governance/wgi/

3.3 Analytical Strategy

The panel data analysis will be conducted using static regression models. The Hausman test will be employed to determine the more appropriate model specification. Diagnostic test is performed to ensure the robustness of the estimates.

3.3.1 Pooled OLS Regression

The panel regression model is specified as:

$$SDG_{it} = \alpha + \beta_1 Internet_{it} + \beta_2 FBB\_it + \beta_3 GDP_{it} + \beta_4 Edu_{it} + \beta_5 Urban_{it} + \beta_6 Gov_{it} + \varepsilon_{it}$$

where:

SDG_{it}: Sustainable Development performance for country *i* in year *t*
$Internet_{it}$: Internet penetration rate (% of population)
FBB_{it}: Fixed Broadband subscriptions per 100 people
GDP_{it}: GDP per capita (constant USD)
Edu_{it}: Education index (proxied by mean + expected years of schooling)
$Urban_{it}$: Urbanization population (% of population)
Gov_{it}: Government effectiveness index
ε_{it}: Error term

3.3.2 Fixed Effects (FE) Model

The fixed effect regression model is specified as:

$$SDG_{it} = \alpha_i + \beta_1 Internet_{it} + \beta_2 FBB_{it} + \beta_3 GDP_{it} + \beta_4 Edu_{it} + \beta_5 Urban_{it} + \beta_6 Gov_{it} + \varepsilon_{it}$$

where:

αi: country-specific intercept that captures all time-invariant characteristics of each country

3.3.3 Random Effects (RE) Model

The random effect regression model is specified as:

$$SDG_{it} = \alpha + \beta_1 Internet_{it} + \beta_2 FBB_{it} + \beta_3 GDP_{it} + \beta_4 Edu_{it} + \beta_5 Urban_{it} + \beta_6 Gov_{it} + u_i + \varepsilon_{it}$$

where:

u_i: country-specific random effect, assumed to be uncorrelated with the regressors

By applying this methodological framework, the study seeks to generate empirically grounded insights into how varying levels of digital adoption influence sustainable development trajectories across OIC countries, taking into account both structural differences and policy environments.

4. Results and Discussion

Table 2: Descriptive Analysis

Variable	Observation	Mean	Standard Deviation	Min	Max
SDG	60	69.9453	2.0876	66.58	75.11
Inernet	60	73.3016	13.9316	39.4	97.7
FBB	60	11.5933	4.8625	2.9713	22.5049
GDP	60	7600.434	3079.33	2988.781	13105.66
Edu	60	10.4022	1.1435	7.8	12.5472
Urban	60	72.6625	11.2787	56.423	92.02
Gov	60	0.0938	0.4765	-1.0224	1.145935

Table 2 shows the descriptive results for each of variables used in this research. For example, SDG rate indicates a moderate variation with min 66.58, max 75.11, mean 69.95 and small standard deviation. These values show moderate variation in SDG rate which suggest stable development performance across the sample. Contrast to the Internet usage variable showed a wide range between 39.4% and 97.7%, with a mean of 73.30%, indicating diverse digital access levels. Meanwhile, Fixed broadband subscriptions (FBB) had a lower average, with mean 11.59, revealing room for digital infrastructure improvement. Then, GDP per capita shows an economic disparity and diverse stages of development between the countries. Education (Edu) and urbanization (Urban) levels were relatively consistent, while the governance effectiveness variable (Gov) indicating varying levels of government effectiveness across observations.

Table 3: Panel Unit Root Test

Variable	Levin-Li-Chu	
	Level	First - Difference
SDG	-4.1520***	-1.6950**
Internet	-4.3238***	-4.0622***
FBB	-0.6671	-4.2867***
GDP	2.8376	-3.7986***
Edu	-2.8654***	-0.4028

Urban	-6.5734***	-3.4751***
Gov	-0.3163	-4.6534***

NOTES: *, ** and *** are significant at 10%, 5% and 1% respectively

The panel unit root test was applied to determine the stationarity of the data used in this research. Table 3 shows the Levin-Lin-Chu unit root test's result for each of the variable used. According to Table 3, most variables were stationary at level, particularly SDG, Internet, Edu, and Urban. However, FBB, GDP, and Gov were found to be non-stationary at level and become stationary only after first differencing. Therefore, these variables were differenced to ensure stationarity before any analysis is carried out. Ensuring stationarity is critical for avoiding spurious regression results in panel data analysis.

Table 4: Panel Regression Analysis: Static Estimation

Variables (Dependent Variable – SDG)	Panel OLS (Robust Standard Error)	Fixed Effect	Random Effect	Fixed Effect (Robust Standard Error)
Internet	0.0086	0.0356***	0.0086	0.0356***
FBB1	0.9017***	0.0936	0.9017***	0.0936
GDP1	0.0004**	0.0001	0.0004**	0.0001
Edu	0.0479	-0.7916***	0.0479	-0.7916***
Urban	-0.0845***	0.3542***	-0.0845***	0.3542***
Gov1	2.5666	-0.5659	2.5666	-0.5659
Constant	74.4726***	49.8017***	74.4726***	49.8017***
N	54	54	54	54
Hausman Test	-	Pv > χ^2 = 65.42***		-

NOTES: *, ** and *** are significant at 10%, 5% and 1% respectively

As shown in Table 4, the static panel regression models were estimated using both fixed and random effects. The Hausman test indicated that the fixed effect model is preferred over Random Effect, with a significant p-value below 0.01. Within the fixed effects model, internet penetration (Internet) had a positive and statistically significant relationship with SDG performance. This suggests that, holding other factors constant, a 1 percentage point increase in internet usage is associated with a 0.0356-point increase in the SDG index. This result indicating the role of digital inclusion in promoting sustainable development. This finding aligns with the Technology Diffusion Theory (Rogers, 1962) and consistent with empirical findings by ElMassah and Mohieldin (2020). The relationship between internet penetration and SDG performance is shown in Figure 1.

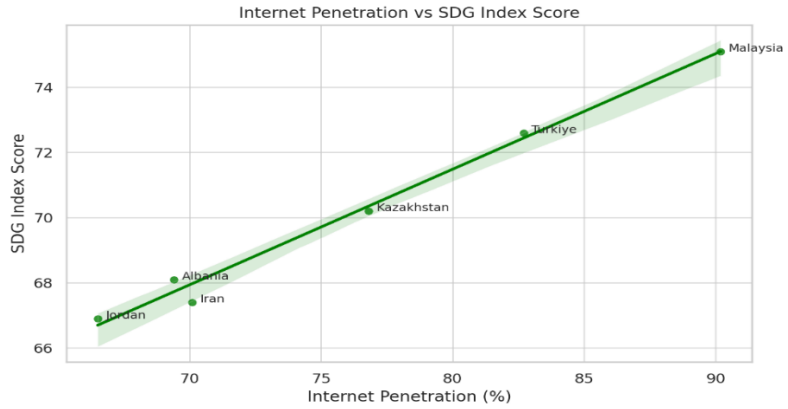

Figure 1: The relationship between Internet Penetration and SDG Performance

Figure 1 shows a clear positive linear relationship between internet penetration and SDI performance. Countries with higher internet penetration (like Malaysia and Türkiye) also tend to have higher SDI index scores, supporting the regression result that internet access is a strong enabler of sustainable development.

Fixed broadband (FBB1) was only significant in the pooled OLS model but not in the fixed effects. This suggests that, after accounting for country-specific fixed effects and time-variant controls, changes in broadband subscription levels do not have a consistent or immediate impact on overall SDG performance. These may be because of several reasons such as time lag effects, inequitable access, and affordability and usage barriers among others. This result is consistence with empirical findings by Kim et al. (2018). The relationship between fixed broadband subscription and SDG performance is shown in Figure 2.

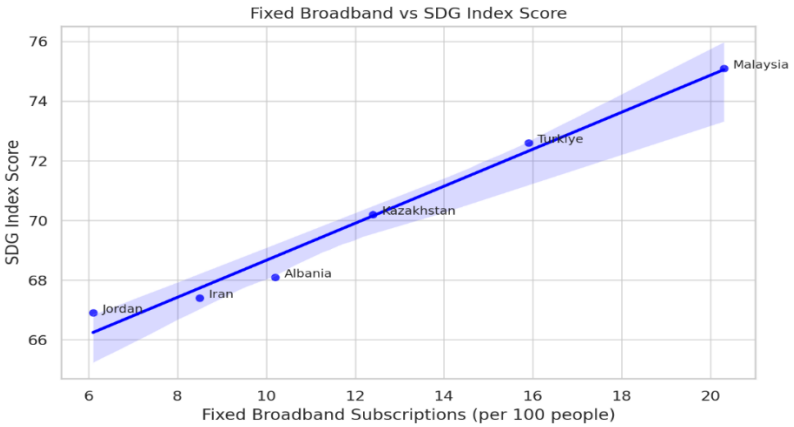

Figure 2: The relationship between Fixed Broadband Subscriptions and SDG Performance

Figure 2 shows the relationship between fixed broadband subscriptions and SDG performance that appears to be weaker and more scattered. This is aligned with the statistically insignificant coefficient found in the fixed effects model. While countries like Malaysia have both high broadband and SDG scores, the pattern is not consistent across the sample. These graphs visually reinforce the key finding related to the explanatory variables where internet

penetration shows a stronger and more consistent relationship with SDG outcomes than fixed broadband access in the current context of OIC countries.

GDP growth (GDP1) showed a positive and significant relationship with SDG. That means short-term increase in economic growth supports better development outcomes. This finding is consistent with the Endogenous Growth Theory (Romer, 1986) and empirical finding by Sachs et. al (2019). Surprisingly, education (Edu) exhibited a negative and significant impact on SDG in the fixed effect model. This unexpected result could reflect inefficiencies in the education system or disparities of education level across the countries and it affect on the overall development. One possible explanation is that the education system in some countries may prioritize conventional academic achievement without incorporating SDG-aligned content such as environmental literacy, social responsibility, and sustainable practices. This aligns with critiques in the literature, such as by Filmer and Prichett (1999).

Urbanization (Urban) displayed differing effects between the models. For positive and statistically significant coefficient in the fixed effect model, it supports the argument that higher urbanization contributes positively to SDG progress and is aligns with the Urban Transition Theory (Brenner & Schmid, 2015) and empirical studies by Angel et.al (2011) and Jedwah & Vollrath (2015). Governance Effectiveness (Gov1), however, did not show a significant effect in any of the static models, suggesting its role may be complex and it is different between the countries. This is accordance with Omar & Inaba (2020) findings and may suggest another study with longer time horizons.

5. Discussion and Conclusion

This study investigated the impact of digital adaptation measured through internet penetration and fixed broadband subscription on Sustainable Development Goal (SDG) performance across six upper-middle-income OIC countries namely Albania, Iran, Jordan, Kazakhstan, Malaysia, and Türkiye. Using panel data from 2014 to 2023 and applying static panel data estimation methods, the study assessed how digital infrastructure contributes to sustainability outcomes while controlling for key socio-economic and institutional factors such as GDP growth, education, urbanization, and governance. The results provide compelling evidence that internet penetration plays a significant and positive role in advancing SDG performance. This finding supports the notion that expanding access to digital networks enhances public service delivery, facilitates inclusive growth, and strengthens citizen engagement; the core elements of the 2030 Agenda. In contrast, fixed broadband subscription did not exhibit a statistically significant impact, suggesting that broader digital inclusion, rather than technical bandwidth alone, is more crucial in the short to medium term for sustainability outcomes.

Among the control variables, GDP per capita growth and urbanization were positively associated with SDG performance, highlighting the importance of economic development and smart urban planning. Interestingly, the education index showed a negative and significant relationship with SDG outcomes, potentially indicating a gap between education quality and sustainability relevance, or a mismatch between educational investments and labour market needs. Government effectiveness, while theoretically important, showed mixed and statistically insignificant results, suggesting that its influence may be more long-term or mediated by other institutional factors.

While this study provides important insights into the relationship between digital adaptation and SDG performance across selected OIC countries, several limitations must be acknowledge. Firstly, the analysis is based on panel data from only six upper-middle-income OIC countries over period 2014 – 2023 which may limit the generalizability of the findings. The results reflect the experiences of relatively similar economics in term of income level, and may not apply to lower-middle-income or lower-income OIC members or non-OIC countries with different development trajectories. Secondly, some variables such as government effectiveness and SDG performance are based on composite indices which may not fully capture on-the-ground realities or may contain measurement error. Thirdly, although fixed effect estimation are used to control for unobserved heterogeneity, this study relies on statis panel data models which do not fully capture potential dynamic effects and lastly, this study do not explicitly control for institutionally quality beyond governance effectiveness nor does it address cultural, religions or political dynamics that may influence policy implementation and public behavior regarding both digital adaptation and sustainability performance.

Based on these discussions, several key policy implications emerge. First, OIC countries should prioritize investments in universal internet access, particularly in underserved regions, to harness its transformative potential for sustainable development. Second, policymakers should align education systems with sustainability competencies and digital skills. Third, urbanization strategies must emphasize inclusivity, infrastructure readiness, and environmental sustainability to amplify their positive impact on the SDGs. Finally, while governance quality remains vital, its role may require a longer time horizon and greater policy coherence to manifest in measurable SDG progress. In conclusion, this study reinforces the critical role of digital adaptation as a catalyst for sustainable development in OIC economies. It contributes to the growing literature at the intersection of digital transformation and sustainability, and calls for integrated digital and policy frameworks to accelerate progress toward the 2030 Agenda.

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