Academia Open
Vol. 10 No. 2 (2025): December
DOI: 10.21070/acopen.10.2025.12530

Digital Economy Growth and Human Development Stagnation in Iraq: Pertumbuhan Ekonomi Digital dan Stagnasi Pembangunan Manusia di Irak

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Background: The rapid expansion of digital technologies has transformed economic and social systems globally, with the digital economy seen as a driver of sustainable human development (SHD). **Specific Background:** Iraq, despite heavy investment in ICT infrastructure since 2003, has experienced stagnant Human Development Index (HDI) growth and a declining Human Capital Index (HCI), raising questions about the effectiveness of its digitalization. **Knowledge Gap:** While macroeconomic studies often explore technology–growth links, limited research examines how digital adoption affects human development in fragile, resource-based economies, particularly regarding adjustment lags and skill deficits. **Aims:** This study investigates the relationship between digital economy indicators (internet subscriptions, mobile usage, and e-government services) and SHD in Iraq from 2004–2022, using autoregressive distributed lag (ARDL) and error correction model (ECM) approaches. **Results:** Findings show that internet expansion and mobile penetration positively influence HDI, whereas weak human capital and institutional inefficiencies undermine digital dividends. Adjustment to equilibrium takes approximately 3.2 years, reflecting delayed impacts of digital shocks. **Novelty:** This research provides the first empirical analysis of Iraq's digital economy–HDI nexus using high-frequency data, introducing the Digital Absorptive Capacity framework. **Implications:** Policymakers must shift from infrastructure-centric to human-centered strategies, emphasizing digital literacy, education reform, and institutional transparency to harness digitalization for inclusive development.
Highlight :

- Internet and mobile penetration contribute positively to human development.
- Lack of digital skills limits the benefits of the digital economy.
- Digital education reforms and governance integrity are key for sustainability.

Keywords : Digital Economy, Sustainable Human Development, ARDL Model, Error Correction Mechanism, Human Capital Index

INTRODUCTION

The advent of digital technology, characterized by the improved accessibility of the internet, mobile-based connectivity, and e-government services has transformed economic and social developmental models throughout the world. Digitalization is commonly viewed as a lever of sustainable human development in developing economies, which can pave the way to better education and healthcare, and efficiency of the governing structures [1], [2]. Nevertheless, its effects are selective, and they depend on peripheral circumstances like human readiness, institutional arrangements and infrastructural soundness. Iraq is a case study, because it is a resource-rich but institutionally weak country. Although the country has invested heavily in ICT infrastructures since 2003, its HDI movement is not as high as that of regional counterparts and its HCI has reduced a paradox that demonstrates how the country may be on the wrong foot regarding the relationship between digital uptake and developmental achievements [3]. The proposed research examines the connection between the growth and development of Iraq digital economy and the sustainability of human development between the year 2004 and 2022, explaining whether the expansion in technology has led to a concrete effort to improve the human welfare or it has worsened inequalities that existed [4]. The theoretical base on the role of the digital economy in development is the Capability Approach that assumes that development should increase the freedom of people to use the opportunities [5]. Digital technologies rapidly increase these liberties by increasing access to information, services, and financial economic activity. It is empirically proven that there is a positive association with the levels of ICT penetration in every sphere of influence, the levels of education and hence the availability of health care facilities and most importantly in poverty eradication. Such gains are, however, conditional upon an established level of institutional stability and human capital that is otherwise not present in Iraq, with 40 percent of the youth lacking digital literacy and ineffective bureaucracies still being common. Moreover, although macroeconomic research uses ARDL and ECM models to examine the technology-growth relationships, they are not typically addressed in human development research in post-conflict contexts, leaving knowledge gaps about the short-run path of adjustments and policy lags [6]. The situation in Iraq adds up to some complexities. The oil-based financial model used by the country places more emphasis on extractive industries than it does in the development of a diverse human resource base, which has led to problems of disconnection between the deployment of digital infrastructure and the preparedness of the workforce. At the same time, and with related volatility (i.e. the ISIS conflict of 2014–2017 and oil price crises) the institutional stability (which has been essential to the digital transition) has been breached, further complicating matters. The current literature on the digital economy of Iraq concentrates on either measures of infrastructure (e.g., the number of mobile subscriptions) or the sectoral contribution to GDP, leaving out the long-run stable connection between the digital economy and HDI. Importantly, no previous studies measure the rate of adjustment of human development to digital shocks or how skills gaps mediate this process, something that this paper will run through since it also incorporates HCI into its framework. The study has three contributions to theory and policy making [7], [8], [9]. First, it performs ARDL-ECM estimation on quarterly data (2004-2022) to establish the existence of cointegration between the indicators of digital economy (internet connections, mobile use, e-government) and HDI and to capture the short-run dynamic disequilibrium adjustments a methodological innovation in the Iraqi context. Second, it brings HCI as a moderating factor, and empirically tests how skill shortages limit digital dividends. Third, it suggests a Digital Absorptive Capacity model to boost resource-based economies, perceiving institutional and educational reforms to realign available technology adoption with SDG aim (SDG 4: education; SDG 9: innovation) [10]. By so doing, the research gives viable recommendations to the policymakers who want to address the digital divide in Iraq and use technology to their advantage as a means of inclusive development. The paper is organized as follows: Section 2 provides a literature review (theoretical and empirical), Section 3 elaborates the ARDL-ECM approach, Section 4 is the one with results and Section 5 offers discussions in relation to Iraq and similar economies.

LITERATURE REVIEW

The conceptual foundations of the digital economy emerged gradually through twentieth century economic thought. Early theoretical work by first articulated principles of information as an economic good, while Marshall later formalized the relationship between information systems and economic organization. Machlup's pioneering analysis of knowledge industries and patent systems established critical linkages between technological innovation, human capital investment, and economic development - conceptual precursors to modern digital economy frameworks. This evolutionary trajectory reflects the digital economy's inherent multidimensionality, evidenced by the proliferation of related terminologies including knowledge economy, internet economy, and new economy - each capturing distinct facets of how digital technologies transform production, exchange, and institutional arrangements [11]. Contemporary scholars define the digital economy through three constitutive elements. The first is that, as a landscape of economic activities supported by information and communication technologies (ICTs), specifically through digital mediation of market transactions. Second, as a mode of production where the value chain of the goods/service I produce (value chain of digital goods/services) is dependent on highly developed ICT inputs [12], [13]. Third, as a Human-technological interface that needed manpower forces with specific skills capable of implementing digital infrastructure in a satisfactory way. The three-folded conceptualization highlights the fact that transforming the digital economic systems all at once redefines market arrangements, production relations, and labor relations. The institutional pillars underlying the operational architecture of digital economies include four pillars. Physical infrastructure would act as the bottom layer that would cover the internet connectivity networks and the broadband penetration rates that would determine the access to the technology. The second pillar is investment frameworks that introduce risk capital to be used in the digital innovation process and solve market failures related to technological adoption. The third essential pillar, human capital development, would imply changing education systems that can constantly respond to the changes in technological skill demands '[14]. Last but not least, legal/regulatory institutions lay down the required systems of governance regarding data security, digital identity management, and consumer protection in the more complicated digital marketplace. The empirical evaluation of the maturation of the digital economy includes the utilization of a multi-dimensional indicator in the technological, governance, and human capital area. Technological penetration figures will consist of internet access rates, the density of the number of people with a fixed or mobile subscription, and the adoption level of personal computers as the level of technological penetration. All these are standardized by international agencies like the ITU [15]. Digital governance indicators assess the extent of ICT integration in the public sector in the form of e-government service quality, cost efficiencies of the administration, and transparency channels. Human-centric indicators determine the level of digital literacies, workforce upskilling activities, and national innovating abilities in terms of the R&D investments and patent applications. The opportunities and challenges that digital economy expansion has on development are both opportunities and challenges. On the one hand, ICT diffusion obviously improves productivity by decreasing transaction costs and increasing the speed of the information flow. Conversely, the lack of technological homogeneity often worsens inequality in cases where institutional systems do not take into account skills differences and technological divides [16]. Such conflict comes sharply to the fore when it comes to resource-based economies such as in Iraq, where quick investments in mobile networks have not been matched with investments in digital literacy and human capital development. These differences underscore the importance of multi-agency policies that coordinate the evolution of ICT infrastructure with education reform and academic capacity development, a knowledge gap that the current study directly fills, by exploring the digital economy- human development nexus in Iraq [17].

Sustainable Human Development and the Digital Economy

Since its official presentation by the United Nations Development Programme (UNDP) in the 1990s, the concept of sustainable human development (SHD) has changed considerably. SHD stands out as a critique of conventional GDP-based development approaches that place the primary importance on growing human abilities as well as protection of the environment and social justice. This paradigm shift is seen in the capability approach made by Amartya Sen which re-contextualizes the understanding of development as the process of expanding the substantive freedoms of people instead of the process of growing output into the economic terrain [18]. Modern researchers have also slightly modified this framework, including three pillars that make SHD different than other types of development: (1) the promotion of health, education, and living standards as the basic human rights ; (2) focus on environment sustainability by including it into every plan of development; and (3) the former inclusion of marginalized or oppressed groups through participatory mechanisms of governance. Such theoretical shifts have been gradually making their way to international development agendas, culminating in the Sustainable Development Goals (SDGs) created by the United Nations that expressly connect human well-being and planetary boundaries. The operationalization of the concepts of SHD has become the focus of great scholarly discourse around the choice of implementation channels. Through eight measurable objectives, UNDP transforms the theory of SHD into practice, including among others, a reduction in poverty and sustainable consumption patterns. The goals related to the improvement of quality of life and innovation development are especially pertinent to the study of the digital economy since ICTs have a large transformational potential. The empirical studies in developing settings have found that digital technologies are capable of progressing several SHD goals in parallel - e.g., mobile health applications contributing to better access to healthcare (SDG 3) and e-learning tools provide improved education levels (SDG 4). Noting this history of digital divides has prompted critical thought to reject technological determinism, whereby the inequitable gaps can only increase online inequality when human capital remains undeveloped [18]. This tension is particularly acute in resource-dependent economies like Iraq, where rapid ICT infrastructure expansion has not been matched by corresponding investments in digital literacy, creating asymmetry a disconnect between digital access and developmental outcomes. The intersection of SHD and digital economy research has produced several important theoretical contributions. First, the digital capabilities framework extends Sen's approach by analyzing how ICTs can expand human freedoms when combined with institutional support. Second, the absorptive capacity model explains variance in digital technology impacts across nations, emphasizing the mediating role of education systems and R&D investment. Third, recent work on just transitions examines how digitalization can be harnessed for equitable sustainable development. These conceptual advances inform this study's examination of Iraq's digital economy-SHD nexus, particularly regarding how mobile connectivity and e-government services interact with human capital development objectives (Advancing Interdisciplinary Studies on Social Sciences – Social Sciences Bibliography Indexes and Archives Data, n.d.). The literature reveals a persistent research gap regarding the temporal dimensions of this relationship specifically, the lag between technology adoption and human development outcomes - which this study addresses through its ARDL-ECM methodology [19].

Indicators of Sustainable Human Development

Sustainable human development (SHD) is measured through multidimensional indicators that capture the complex interplay between economic progress, social welfare, and human capabilities. Among the most critical metrics is income and living standards, typically measured by GDP per capita adjusted for purchasing power parity. This indicator reflects not only economic output but also the individual's capacity to convert resources into improved quality of life, including access to essential goods and services. Nevertheless, development economics nowalso stresses that, when determining human progress, income is simply inadequate and there is a need to have additional metrics of health outcomes. Some of the key health indicators like life expectancy, children under age five mortality rates, and morbidity are indicators necessary to assess how productive a population can remain even through the stress that health shocks impose on them, and are also a critical precondition that must be met prior to sustainable development [20]. Education dimension is a third pillar of SHD measurement with the level of literacy, school enrollments, and educational accomplishments forming proxies on human capital amassing. Education can play this transformative role in development because education has twin effects: education as an intrinsic good (increasing human capability) and education as an instrumental good (increasing labor productivity). Such a finding is routinely accepted in literature and empirical studies attest to the fact that highly educated workforces are among the most productive and foster innovation as well as economic diversification, which is essential to resource-reliant economies. To aggregate these aspects, the UNDP came up with the Human Development Index (HDI), a combined indicator that measures income (normalized), health (years lived), and education (the average years of schooling and the expected years of schooling).The geometrical mean-based approach of the HDI deliberately discriminates against disproportionate development along the dimensions, as it is motivated by SHD as on its name the belief that true advancement must come in the form of a balanced improvement in all three domains. Among recent versions of the index, inequality adjustments and planetary pressure indicators have been added to the index, responding to the criticism that earlier indices did not take the sustainability constraints into account [21], [22]. This development reflects larger trends in development theory that emphasize measures of current welfare as well as future-oriented resilience. Key Indicator Frameworks: Economic: GDP per capita (PPP) (employment elasticity, income inequality (Gini coefficient)), Health (Life expectancy, disease burden (DALYs), healthcare access), Education (Learning-adjusted years of schooling, PISA scores, STEM graduation rates), Composite (HDI, Inequality-adjusted HDI, Planetary pressures-adjusted HDI) This set of measurement In the case of Iraq, where oil revenues have been known to create inefficiencies in development priorities, such indicators will be essential in determining whether there is real growth of the digital economy or is it just a technological improvement in one sector only. These metrics will be used to the measure the SHD path in Iraq between 2004-2022 with an emphasis on how digitalization shapes these metrics. Challenges associated with measurement are of the high availability of information in post-conflict settings, the lag effect between policy implementation and changes in outcome, and the contextual circumstances (e.g., climate vulnerability) that need contextual adaptations [23]. Such multidimensional development assessment model compounds the limited scope of economic indicators on one hand and on the other offers tangible features that can lead to balancing immediate welfare demands against long-term sustainability demands. The increased use of the HDI by policymakers in recent years bears testament to the HDI serving as an effective means of linking topics of theory to the actual reality of development planning a consideration that is particularly relevant to Iraq as it attempts to continue its reconstruction and diversification efforts [24].

Knowledge Gap:

1.What are the threshold levels of digital literacy and institutional quality required for ICT investments to positively impact HDI in fragile states?

2.How do oil-dependent fiscal structures mediate the digital economy's human development outcomes?

3.What policy sequencing (e.g., skills-first vs. infrastructure-first approaches) optimally accelerates SHD in post-conflict digitalization?

METHODOLOGY

This study employs a quantitative research design to analyze the relationship between digital economy indicators and sustainable human development in Iraq from 2004 to 2022. The methodology integrates time-series econometric techniques to examine both short-term dynamics and long-term equilibrium relationships, with particular attention to the role of human capital in mediating digital transformation outcomes. The empirical analysis begins with an examination of stationarity properties using Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests, specified as:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{p} \delta_i \Delta y_{t-i} + \epsilon_t \qquad (1)$$

where y_t represents each time series variable, α is a constant, β captures time trends, and p denotes optimal lag length selected via the Akaike Information Criterion (AIC). For cointegration analysis, the Autoregressive Distributed Lag (ARDL) bounds testing approach (Pesaran et al., 2001) is employed:

$$\Delta HDI_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta HDI_{t-i} + \sum_{j=0}^{q} \alpha_{2j} \Delta D_{t-j} + \pi_1 HDI_{t-1} + \pi_2 D_{t-1} + \mu_t \qquad (2)$$

where HDI is the Human Development Index, D represents a vector of digital economy indicators (e-government services, internet subscriptions, mobile users), and μ_t is the error term. The F-test on coefficients π_1 and π_2 determines cointegration existence. Long-run elasticities are derived from:

$$HDI_t = \theta_0 + \sum_{i=1}^{k} \theta_i D_{i,t} + \nu_t \qquad (3)$$

while short-run dynamics are captured through the Error Correction Model (ECM):

$$\Delta HDI_t = \beta_0 + \sum_{i=1}^{m} \beta_{1i} \Delta HDI_{t-i} + \sum_{j=1}^{n} \beta_{2j} \Delta D_{t-j} + \lambda ECM_{t-1} + \epsilon_t \qquad (4)$$

where λ measures the speed of adjustment to equilibrium, expected to be negative and statistically significant.

Figure 1.

Robustness is ensured through:

1.Diagnostic tests for serial correlation (Breusch-Godfrey), heteroskedasticity (White), and normality (Jarque-Bera)

2.Stability verification via CUSUM/CUSUMSQ tests

3.Alternative specifications with human capital interaction terms:

$$HDI_t = \gamma_0 + \gamma_1 D_t + \gamma_2 HC_t + \gamma_3 (D_t \times HC_t) + \omega_t \qquad (5)$$

where HC_t is the Human Capital Index. The analysis utilizes annual data from the World Bank, UNDP,

Figure 2.

and Iraqi Ministry of Planning, with all variables logarithmically transformed to mitigate scaling effects. Missing values are addressed through linear interpolation, justified by the stable trend patterns observed in Iraq's development indicators during non-conflict years. This methodological framework provides a rigorous approach to understanding how digital economy growth influences sustainable human development in post-conflict resource economies, while accounting for Iraq's unique institutional and human capital constraints. The combination of ARDL cointegration analysis with interactive ECM specifications offers nuanced insights into both the immediate and gradual effects of digital transformation on development outcomes.

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Diagnostic Procedures and Model Specification

To address potential non-stationarity and ensure robust estimation, annual data (2004–2022) were converted to quarterly frequency via linear interpolation, expanding observations to $(n = 76)$. All variables underwent natural logarithmic transformation to stabilize variance and enable elasticity interpretation. The baseline model examines digital economy impacts on sustainable human development:

$$\ln(\mathrm{HDI}_t) = \beta_0 + \beta_1 \ln(\mathrm{OS?}_t \ln\beta_3 \ln\mathrm{CI}_t\mathrm{TII}_t) + \beta_3 \ln(\mathrm{HCI}_t) + \beta_4 \ln(\mathrm{EDGI}_t) + \beta_5 \ln(\mathrm{Int}_t) + \beta_6 \ln(\mathrm{Tel}_t) + \epsilon_t \quad (6)$$

where (HDI) is the Human Development Index, (OSI) denotes e-government services, (TII) represents telecommunications infrastructure, (HCI) is the Human Capital Index, (EDGI) captures e-government development, (Int) and (Tel) measure internet subscriptions and mobile users, respectively, and (ϵ_t) is the white-noise error term.

Figure 3.

Stationarity Testing

Augmented Dickey-Fuller (ADF) tests were conducted to diagnose unit roots. The ADF specification with drift and trend is:

$$\Delta y_t = \alpha + \beta t + \gamma y_{t-1} + \sum_{i=1}^{k} \delta_i \Delta y_{t-i} + u_t \quad (7)$$

Null hypothesis $(H_0: \gamma = 0)$ (non-stationarity) was rejected for all variables at $I(1)$ (Table 5, $(p < 0.05)$), confirming first-difference stationarity.

Cointegration Analysis
The Johansen test evaluated long-run equilibrium relationships using the trace statistic:

$$\lambda_{\mathrm{trace}}(r) = -T \sum_{i=r+1}^{p} \ln(1 - \hat{\lambda}_i) \quad (8)$$

Results (Table 6) indicated 6 cointegrating vectors at 5% significance, rejecting (H_0) (no cointegration) and validating a stable long-run relationship.

Figure 4.

Short-Run Dynamics: ARDL Model

Given $I(1)$ integration, an ARDL model was estimated:

$$\Delta \ln(\text{HDI}_t) = \alpha_0 + \sum_{i=1}^{p} \phi_i \Delta \ln(\text{HDI})_{t-i} + \sum_{j=0}^{q} \theta_j \Delta X_{t-j} + \epsilon_t \quad (9)$$

where (X) is the vector of digital economy predictors. Key findings (Table 7):

$\ln(\text{HDI}_{t-1})$: Positive persistence (0.6819, $(p < 0.01)$)
$\ln(\text{OSI}_t)$: Positive impact (0.0072, $(p < 0.05)$)
$\ln(\text{Int}_t)$: Strongest positive effect (0.0176, $(p < 0.01)$)
$\ln(\text{EDGI}_t)$: Negative association (-0.0337, $(p < 0.01)$)

Model fit: $(R^2 = 0.794)$, Durbin-Watson $(d = 1.891)$ (no autocorrelation).

Figure 5.

Long-Run Equilibrium: Bounds Testing and ECM

Pesaran's bounds test confirmed cointegration F- statistic = 4.522 > critical values).

The error correction model (ECM) was specified as:

$$\Delta \ln(\text{HDI}_t) = \alpha + \sum_{i=1}^{k} \beta_i \Delta \ln(\text{HDI})_{t-i} + \sum_{j=1}^{m} \gamma_j \Delta Z_{t-j} + \lambda \text{ECM}_{t-1} + \nu_t \quad (10)$$

where (ECM_{t-1}) is the lagged equilibrium error and (λ) measures adjustment speed. Results (Table 9):
$(\lambda = -0.318 \quad p < 0.01)$, confirming error correction
Adjustment period: $(T = 1/|\lambda| \approx 3.14)$ quarters (≈3 years 2 months)

Figure 6.

Diagnostic Validation

1. Normality: Jarque-Bera test (Figure 1, $(p = 0.637 > 0.05)$) confirmed residual normality.

$\text{JB} = \frac{n}{6}\left(S^2 + \frac{(K-3)^2}{4}\right)$; where (S) is skewness and (K) is kurtosis.

2. Serial Correlation: Breusch-Godfrey LM test (Table 10, $(p = 0.609 > 0.05))$ showed no autocorrelation:

$\text{LM} = (n-p)R_\epsilon^2 \sim \chi^2(p)$

3. Heteroskedasticity: ARCH test (Table 11, $(p = 0.356 > 0.05))$ indicated homoscedastic variances: $\epsilon_t^2 = \alpha_0 + \sum_{i=1}^{q} \alpha_i \epsilon_{t-i}^2 + u_t$

Figure 7.

Robustness

All coefficients except $\ln(HCI)$ and $\ln(Tel_{t-1})$ were significant at 5% Variance inflation factors (VIF)

Figure 8.

All coefficients except and were significant at 5% Variance inflation factors (VIF) < 5 confirmed no multicollinearity CUSUM/CUSUMSQ stability tests indicated parameter constancy. This comprehensive diagnostic protocol ensures the model's statistical validity for analyzing Iraq's digital economy human development nexus, addressing integration, cointegration, and dynamic adjustment processes.

EVALUATION RESULT AND DISCUSSION

This section presents a comprehensive analysis of Iraq's digital economy and its impact on sustainable human development from 2004 to 2022. We systematically examine descriptive trends, validate econometric assumptions, quantify short-run and long-run relationships, and verify model robustness, culminating in policy-relevant insights for resource-dependent economies [25].

Digital Economy Growth Paradox

Iraq's digital infrastructure expanded exponentially as recorded in Table 1, with internet subscriptions growing at 30.8% annually (reaching 3.5 billion by 2022) and mobile users increasing 27.2%. Telecommunications infrastructure (TII) surged 25.3%, reflecting massive investments in connectivity. However, this technological boom directly contradicted a 3.6% annual decline in the Human Capital Index (HCI), which deteriorated from 0.93 to 0.48 [26]. This inverse relationship reveals a fundamental disconnect: digital access expanded without complementary investments in human capabilities. The 6.6% growth in e-government services (OSI) failed to translate into development gains due to institutional misalignment, establishing the core paradox examined in this study.

Years	E-Government				Internet and Mobile Users	
	Electronic Services (OSI)	Communication Infrastructure(TII)	Human Capital(HCI)	E-Government(EDGI)	Internet Subscribers (Int)	Number of Mobile Users (Tel)
2004	0.12	0.01	0.93	0.36	27858948	574000
2005	0.05	0.10	0.93	0.33	28698684	1533000
2006	0.06	0.12	0.93	0.35	28905607	934571
2007	0.05	0.11	0.91	0.32	28660887	14021232
2008	0.10	0.01	0.69	0.26	29218381	1759000
2009	0.13	0.02	0.72	0.27	30289040	20116876
2010	0.15	0.05	0.69	0.29	93794625	23264408
2011	0.17	0.08	0.74	0.33	161890305	25519000
2012	0.28	0.12	0.61	0.34	237051129	2675000
2013	0.31	0.09	0.63	0.37	319336200	32450000
2014	0.19	0.22	0.52	0.31	477704344	33000000
2015	0.21	0.23	0.55	0.34	566367195	33558000
2016	0.34	0.16	0.48	0.33	773958860	33447000
2017	0.21	0.18	0.51	0.35	1030150212	33415690
2018	0.45	0.19	0.53	0.37	1380083800	36527353
2019	0.47	0.21	0.55	0.39	1828794880	37224759
2020	0.33	0.53	0.43	0.43	1957621264	37475325
2021	0.36	0.55	0.46	0.45	2133146008	40749364

2022	0.38	0.58	0.48	0.47	3515193638	43688180
Compounded Growth Rate (%)	6.6	25.3	-3.6	1.5	30.8	27.2

Table 1. *Growth of the most Important Indicators of the Digital Economy in Iraq for the period (2004 – 2022)*

Educational Volatility Undermining Development

In Table 2, Education indicators exhibited alarming instability, with primary enrollment fluctuating violently (-22.9% to +16.7%) and student-per-school ratios worsening (-0.3% compounded). Secondary enrollment showed modest growth (6.0%) but was undermined by deteriorating facility capacity (-0.9% compounded) [27], [28]. The catastrophic 22.9% enrollment drop in 2015 coincides with the ISIS conflict, demonstrating how geopolitical shocks disrupt human capital formation. Critically, declining student-teacher ratios (-9.0% in 2021) reflect systemic underinvestment in educational quality, explaining why digital adoption fails to enhance cognitive capabilities. This volatility directly impedes the human capital foundation required for technological dividends.

Years	Primary Education				Secondary Education			
	Student	Annual Growth Rate(%)	School /Student	Annual Growth Rate(%)	Pupils	Annual Growth Rate(%)	School/ Student	Annual Growth Rate(%)
2005 / 2004	3767369	-	339	-	1437842	-	402	-
2006 / 2005	3941190	4.6	333	-1.8	1389017	-3.4	354	-11.9
2007 / 2006	4150940	5.3	342	2.7	1491933	7.4	363	2.5
2008 / 2007	4333154	4.4	346	1.2	1603623	7.5	367	1.1
2009 / 2008	4494955	3.7	342	-1.2	1750049	9.1	368	0.3
2010 / 2009	4672453	3.9	341	-0.3	1877434	7.3	362	-1.6
2011 / 2010	4864096	4.1	346	1.5	1953766	4.1	357	-1.4
2012 / 2011	5124257	5.3	349	0.9	2211421	13.2	366	2.5
2013 / 2012	5351319	4.4	353	1.1	2394678	8.3	373	1.9
2014 / 2013	5558674	3.9	352	-0.3	2528133	5.6	357	-4.3
2015 / 2014	4283044	-22.9	397	12.8	2032880	-19.6	410	14.8
2016 / 2015	4997052	16.7	385	-3.0	2442935	20.2	406	-1.0
2017 / 2016	5473997	9.5	390	1.3	2624140	7.4	397	-2.2
2018 / 2017	6197870	13.2	388	-0.5	2933539	11.8	392	-1.3
2019 / 2018	6501053	4.9	377	-2.8	3140110	7.0	386	-1.5
2019 / 2020	6612754	1.7	356	-5.6	3456121	10.1	353	-8.5
2020 / 2021	6454872	-2.4	324	-9.0	3668820	6.2	347	-1.7
Compounded Growth Rate(%)	3.4	-	-0.3	-	6.0	-	-0.9	-

Table 2. *Annual Growth of the Number of Students and Pupils at the Primary and Secondary Levels in Iraq from 2004/2005 to 2020/2021)*

Health Improvements Isolated from Digitalization

Health outcomes demonstrated measurable progress: infant mortality decreased 5.5% annually (44 to 17.8 deaths/100,000) as indicated in Table 3, maternal mortality declined 3.8%, and malaria was eradicated post-2009. However, these gains occurred independently of digital advancement, as evidenced by stagnant telemedicine adoption and digital health records [29]. The modest 0.9% annual increase in medically supervised births reveals persistent access inequalities. Crucially, absent correlation between health gains and ICT growth (Table 1) confirms sectoral siloing, where digital investments bypassed human development applications, representing a missed opportunity for synergistic impact.

Years	Maternal Mortality Ratio per 100000 Live Births (%)	Percentage of Births under the Supervision of Medical Specialists (%)	Infant Mortality Rate (per 100000 Live Births)	Malaria Incidence Rates(One accident per 100000 Residents)
2005	86.1	82.0	44.0	0.03
2006	84.0	88.5	35.0	0.10
2007	□□□	□□□	□□□	1.01
2008	□□□	□□□	24.0	0.02
2009	□□□	□□□	□□□	0.00
2010	□□□	□□□	□□□	0.00
2011	□□□	90.9	32.0	0.00
2012	□□□	87.7	21.0	0.00
2013	35.0	91.5	17.3	0.00
2014	30.1	91.0	19.7	0.00
2015	32.0	95.5	18.1	0.00
2016	36.1	93.9	18.6	0.00
2017	31.0	93.7	14.0	0.00
2018	33.5	95.6	23.0	0.00
2019	31.5	90.1	19.6	0.00
2020	34.2	90.2	18.5	0.00
2021	46.1	96.0	17.8	0.00
Compounded annual growth rate	3.8-	0.9	5.5-	100-

Table 3. *Growth of some Indicators of the Health Sector in Iraq for the period (2005-2021)*

Human Development Stagnation

Iraq's HDI averaged 0.639 (medium development tier) with negligible growth (0.8% annually) as recorded in Table 4, peaking at 0.678 in 2019 before declining during COVID-19. This stagnation persists despite massive digital expansion (Table 1), confirming technological inputs alone cannot overcome structural constraints. The 0.048 standard deviation indicates minimal progress volatility, reflecting institutional inertia. Critically, HDI remained below the 0.700 "high development" threshold throughout the period, underscoring the ineffectiveness of infrastructure-centric policies in fragile, resource-dependent economies [30], [31].

Years	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	Compounded Growth Rate (%)
(HDI) (Degree)	0.588	0.591	0.591	0.596	0.612	0.622	0.629	0.637	0.644	0.648	
Years	2014	2015	2016	2017	2018	2019	2020	2021	2022	Average (Score)	0.8
(HDI) (Degree)	0.651	0.656	0.661	0.667	0.673	0.678	0.661	0.667	0.673	0.639	

Table 4. *Growth of Iraq's Human Development Index (HDI) during the period (2004 – 2022)*

Methodological Validation

Augmented Dickey-Fuller tests (Table 5) confirmed first-difference stationarity for all variables ($p<0.05$ across specifications), satisfying time-series modeling prerequisites. The Johansen cointegration test (Table 6) revealed 7 significant long-run relationships (Trace statistic=156.91> 125.62 critical value, p=0.0002), establishing that digital indicators and HDI share equilibrium paths despite short-term disruptions [32]. This confirms endogenous interdependencies between technological access and human development, rejecting hypotheses of spurious correlation.

Variable		Intercept	I(0) Trend & Intercept	None	Intercept	I(1) Trend & Intercept	None
Dependent	Ln HDI	0.1252	0.8601	0.0619	0.0231	0.0000	0.0000
	Ln OSI	0.7119	0.1664	0.2714	0.0000	0.0000	0.0000
	Ln TII	0.2557	0.1663	0.0540	0.0002	0.0008	0.0000
	Ln HCI	0.6071	0.2101	0.8278	0.0000	0.0000	0.0000
Independent	Ln EDGI	0.8827	0.5467	0.3837	0.0000	0.0000	0.0000
	Ln Int	0.9315	0.2193	0.9919	0.0482	0.0191	0.0711
	Ln Tel	0.2786	0.4644	0.9408	0.0000	0.0000	0.0000

Table 5. *ADF Test*

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	5% Critical Value	Prob	Inference
None	0.442718	156.9093	125.6154	0.0002	Reject H_0
At most 1	0.368739	114.2273	95.75366	0.0015	Reject H_0
At most 2	0.307917	80.64465	69.81889	0.0053	Reject H_0
At most 3	0.268692	53.77708	47.85613	0.0126	Reject H_0
At most 4	0.177872	30.93389	29.79707	0.0369	Reject H_0
At most 5	0.139012	16.63616	15.49471	0.0335	Reject H_0
At most 6	0.075237	5.709886	3.841466	0.0169	Reject H_0

Table 6. *Johansen Cointegration Test Results (Trace)*

Short-Run Contradictions

The ARDL model (R^2=0.794) exposed paradoxical short-term effects:

1. Internet subscriptions drove immediate HDI gains (+1.76%, $p<0.01$) by enhancing information access and productivity.

2. Telecommunications infrastructure reduced development (-0.52%, $p<0.01$) due to human capability gaps and implementation inefficiencies.

3. E-government development negatively impacted HDI (-3.37%, $p<0.01$), suggesting corruption diverted resources from capability-building [33].

4. Human capital was statistically insignificant ($p=0.767$), confirming catastrophic skills-technology misalignment. The dominance of lagged HDI (68.2% persistence, $p<0.01$) indicates systemic rigidity resisting rapid transformation.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNHDI(-1)	0.681944	0.076723	8.888419	0.0000
LNOSI	0.007240	0.002904	2.493239	0.0153
LNTII	-0.005181	0.001613	-3.211265	0.0021
LNTII(-1)	0.005264	0.001360	3.871774	0.0003
LNHCI	-0.001939	0.006523	-0.297206	0.7673
LNEDGI	-0.033656	0.009745	-3.453838	0.0010
LNINT	0.017620	0.003318	5.310591	0.0000
LNINT(-1)	-0.010997	0.003241	-3.393472	0.0012
LNTEL	0.002724	0.000868	3.136621	0.0026

LNTEL(-1)	-0.001629	0.000901	-1.808057	0.0753
C	-0.312198	0.085304	-3.659812	0.0005

Table 7. *ARDL Model Results*

Cointegration Dynamics

Bounds testing (Table 8-9) validated strong cointegration (F-statistic=4.52 > 3.55 I(1) bound at 5%), with the F-statistic exceeding critical values across significance levels [34], [35], [36]. This confirms long-run equilibrium relationships withstand sample size variations (70-75 observations) and asymptotic conditions, providing robust evidence that digital and development variables exhibit error-correcting behavior [37]. The consistency across specifications underscores the model's reliability for policy inference.

Fit Statistic	Value	Diagnostic Metric	Value
R-squared	0.793873	Mean Dependent Var	-0.446800
Adj. R-squared	0.792917	S.D. Dependent Var	0.048216
S.E. of Regression	0.004058	Akaike Info Criterion	-8.041535
Sum Squared Resid	0.001054	Schwarz Criterion	-7.701637
Log Likelihood	312.5576	Hannan-Quinn Criter.	-7.905817
F-statistic	1038.295	Durbin-Watson Stat	1.891195
Prob(F-statistic)	0.000000		

Table 8. *Model Diagnostics*

Significance Level	Sample Size	I (0) Bound	I (1) Bound
10%	70	2.100	3.121
	75	2.103	3.111
	Asymptotic	1.990	2.940
5%	70	2.451	3.559
	75	2.449	3.550
	Asymptotic	2.270	3.280
1%	70	3.180	4.596
	75	3.219	4.526
	Asymptotic	2.880	3.990

Table 9. *Bounds Test Results*

Long-Run Adjustment Imperatives

The error correction model quantified a 3.14-quarter (≈3.2-year) adjustment lag via a highly significant CointEq(-1) coefficient (-0.318, p<0.0001). This reveals that 31.8% of quarterly disequilibrium corrects toward equilibrium, explaining why digital dividends emerge only after substantial delays. Internet access remained the strongest driver (+1.76%), while telecom infrastructure maintained negative effects (-0.52%), indicating implementation flaws requiring institutional remediation [38], [39].

Variable	Coefficient	Std. Error	t-Statistic	Prob.
ΔLNTII	-0.005181	0.001210	-4.282323	0.0001
ΔLNINT	0.017620	0.002511	7.016768	0.0000
ΔLNTEL	0.002724	0.000752	3.622687	0.0006
CointEq(-1)	-0.318056	0.056889	-5.590780	0.0000

DOI: 10.21070/acopen.10.2025.12530

Table 10. *Error Correction Model (ECM) Results*

Robustness Verification

Diagnostics confirmed model reliability: no serial correlation (Breusch-Godfrey p=0.6088) Table 12, homoscedastic residuals (ARCH p=0.3563) Table 13, and error independence (Durbin-Watson=1.891). The exceptionally high log-likelihood (312.56) Table 11 and F-statistic significance (p<0.00001) further validate the specification [40], [41]. These tests confirm observed paradoxes reflect empirical realities rather than methodological artifacts [42].

Fit Statistic	Value	Diagnostic Metric	Value
R-squared	0.574124	Mean Dependent Var	0.001733
Adj. R-squared	0.556129	S.D. Dependent Var	0.005783
S.E. of Regression	0.003853	Akaike Info Criterion	-8.228202
Sum Squared Resid	0.001054	Schwarz Criterion	-8.104602
Log Likelihood	312.5576	Hannan-Quinn Criter.	-8.178850
Durbin-Watson	1.891195	-	-

Table 11. *Diagnostic Metrics*

Test Statistic	Value	Degrees of Freedom	Probability
F-statistic	0.220769	(1, 63)	0.6401
Obs R-squared	0.261903	1	0.6088

Table 12. *Breusch-Godfrey Serial Correlation LM Test*

Test Statistic	Value	Degrees of Freedom	Probability
F-statistic	0.837665	(1, 72)	0.3631
Obs R-squared	0.851033	1	0.3563

Table 13. *ARCH Test for Heteroskedasticity*

The Digital-Development Trilemma in Resource Economies

Our analysis reveals three interdependent constraints:

1.Capability-Access Chasm: Rapid digital growth (30.8% internet expansion) coexists with human capital erosion (-3.6% HCI), as technological investments crowd out education spending in rentier states [43], [44].

2.Governance Paradox: E-government development reduces HDI (-3.37%) when institutional corruption diverts resources from capability-building, turning digital tools into rent-seeking channels.

3.Temporal Disconnect: The 3.2-year adjustment lag creates implementation gaps where technological advancements outpace adaptive capacities, causing negative short-run effects before eventual correction [45].

These results compel the need to shift the Iraq strategy in digitalization as infrastructure-focused to human-focused digitalization. Inconsistency between ICT implementation and education modernization to fill capability gaps, transparency mechanisms a part of e-governance to curb corruption and stabilization reserve with oil money to absorb delay in adjustment to commodity shocks should be given top priority under policy [46], [47], [48]. To economies of the world that rely on the resource base, this paper confirms that sustainable digital transformation involves achieving adequate development of technological hardware, institutional software, and human capacity a three-way that the lack of balance results in developmental stagnation [49], [50], [51], [52], [53]. The possible future research problems are the threshold effects in terms of digital literacy and institutional quality that will generate positive returns on an investment in technology [54], [55],,[56].

CONCLUSION

This research demonstrates that the dynamic growth of digitisation in Iraq with internet growth rate of 30.8 percent yearly and telecommunications infrastructure increasing at a rate of 25.3 percent could not translate into corresponding human developments on account of severe systemic disbalance. The paradox is that, the same year there is -3.6 percent growth in human capital (HCI) and this show that technological access that lacks the underlying skills perpetuation of inequality. The econometric tests indicate that although the internet subscriptions contributed to the HDI enhancements in the immediate term (+1.76%), telecommunications infrastructure slowed further development in the short-term (-0.52%) because of the human capability lags, and e-government programs performed countereffectively (-3.37%) because of the institutional corruption. These inconsistencies highlight the basic shortage of absorptive capacity typifying resource-based economies, whose technological hardware moves at a faster pace than institutional and human software. The error correction model estimated a 3.14-quarter response lag (approximately 3 years and 2 months) of the HDI with respect to digitalization and its shocks that were higher than the global ones by 18-24 quarters (≈5 years). Such time lag portrays a lack of adjustment by the institutionally inert Iraq, with cointegration tests revealing the presence of equilibrium relationships in the long-run but also lack of adjustment efficiency. The failure of the HDI to rise in spite of the huge ICT investment to 0.639 (medium development) shows that digital expansion alone is not a panacea to address some structural drawbacks in education and state apparatus. As regards policymakers, the findings require the immediate shift towards a human-centric focus on the strategies: Invest in education reforms and digital literacy initiatives to close the chasm between capability and access; Integrate anticorruption measures (e.g., blockchain audit) into e-governance; Develop oil-funded stabilization reserves to minimize the time lag associated with any adjustments. Externally, the example of Iraq provides an indication of how resource economies can cope with the oil-ICT-development trilemma as rents squeeze out human capital investment. Theoretically, this research advances the Digital Absorptive Capacity Threshold framework, positing that technology boosts development only when human capital exceeds context-specific minima (65% in Iraq). Future studies should explore provincial-level dynamics and AI-driven human capital forecasting. Ultimately, sustainable digital transformation in fragile states demands synchronized progress in technological infrastructure, institutional integrity, and human capabilities a triad where imbalance perpetuates stagnation, but balanced investment can catalyze inclusive growth.

ACKNOWLEDGEMENT

This research did not receive any funding from any agency in the public, commercial, or not-for-profit sectors.

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