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Research Article

Impact of ICT Adoption, Economic Growth, and Internet Connectivity Phases on Tax Revenue in Tanzania

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Abstract

This study analyses the mixed evidence surrounding the impact of ICT adoption on tax revenue in Tanzania, focusing on ICT investments, ICT imports, internet usage, and broadband penetration. Drawing on the Technology Organization Environment (TOE) framework and Production Theory, the study adopts a positivist philosophy and deductive approach, using 25 years of time-series data. Employing Regressions, Autoregressive Distributed Lag (ARDL) modeling, and Structural Equation Modeling (SEM), it investigates long-term effects, mediation, and moderation. The findings reveal that ICT investments, ICT imports, and broadband penetration positively influence tax revenue over the long term, while internet usage has a negative effect. Economic growth is found to partially mediate the relationship between ICT investments and tax revenue and fully mediate the effects of ICT imports, broadband, and internet usage. Furthermore, internet connectivity phases significantly influence the relationship between broadband penetration and tax revenue, with 3G and 4G technologies amplifying the positive impact, while 2G exhibits no significant effect. The study affirms the long-term impact of ICT on tax revenue and introduces economic growth and internet connectivity phases as mediating and moderating variables respectively. It challenges assumptions about the positive role of internet usage, offering nuanced insights into ICT's fiscal implications. It offers practical insights for policymakers aiming to leverage digital transformation for more effective and inclusive tax systems, particularly as countries transition toward advanced technologies like 5G.

Keywords: ICT adoptions, Economic Growth, Tax Revenue, Internet Connectivity Phases.

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Introduction

Tax revenue plays a critical role in financing essential public services such as infrastructure, healthcare, and education, and is central to achieving the Sustainable Development Goals (SDGs) (Rahman, 2023). In developing countries like Tanzania, tax revenue forms the backbone of public investment and economic development. It enables the government to implement programs that stimulate growth and reduce poverty. Despite this importance, tax collection in many Sub-Saharan African countries, including Tanzania, remains low. Tanzania's tax-to-GDP ratio has stagnated at around 12%, which falls short of the 15% threshold widely considered necessary for sustainable development (Khahro et al., 2020). This shortfall limits the government's capacity to fund infrastructure

and service delivery, in contrast to countries like South Africa, where the tax-to-GDP ratio exceeds 25%, reflecting stronger tax mobilization systems.

One potential solution for improving domestic resource mobilization lies in the adoption of Information and Communication Technologies (ICT). In the digital era, technologies such as e-taxation platforms, broadband networks, and mobile internet usage have been shown to enhance administrative efficiency, reduce compliance costs, and improve tax collection (Bryan & Zuva, 2021). Despite substantial ICT investments, Tanzania's tax system has not fully harnessed the benefits of these digital tools. Although digital platforms are increasingly present, their actual impact on tax revenue remains under-investigated. Prior research offers mixed results: while some studies (e.g. Brun et al., 2020; Mallick, 2021) report limited or even negative effects of ICT on revenue, others (e.g. Bellon et al., 2022; Justice, 2023) find positive correlations. These inconsistencies highlight the need for deeper analysis into how and under what conditions ICT adoption affects tax performance.

This study addresses this gap by examining the role of economic growth as a mediating factor in the relationship between ICT adoption and tax revenue. ICT can indirectly improve tax collection by enhancing productivity and expanding the tax base, which stimulates economic growth. The study investigates this mechanism within Tanzania's context to better understand the pathways through which digital investments translate into fiscal outcomes. Additionally, the moderating role of broadband and internet usage is considered, focusing on how different levels of digital connectivity influence the effectiveness of ICT tools in the tax system. As Tanzania progresses from 2G to 3G and 4G networks with 5G deployment underway; these technological upgrades are expected to transform tax administration by enabling real-time data systems, automation, and wider accessibility to online services (Zhao & Su, 2022). Adegboye et al. (2022) find that although the overall impact of ICT on tax revenue mobilization is positive, the marginal effects are negative, indicating the existence of ICT penetration thresholds. This underscores the importance of understanding how different phases of internet infrastructure can either enhance or constrain the effectiveness of ICT investments in improving tax revenue, which is critical for formulating effective digital policy strategies

Tanzania presents a compelling case for this analysis due to its recent digital transformation efforts (Mbise & Baseka, 2022). The Tanzania Revenue Authority has introduced digital tools such as e-filing and e-payments, aligning with broader national ICT strategies. Yet, research focusing specifically on Tanzania's unique digital and fiscal landscape remains scarce. By exploring how ICT adoption, broadband expansion, and internet usage affect tax revenue, this study aims to contribute meaningful insights for policymakers seeking to strengthen tax systems in similar developing economies.

Theoretical Literature Review

This study applies the Technology Organization Environment (TOE) framework alongside Production Theory to investigate how ICT adoption affects tax revenue in Tanzania. Together, these frameworks offer a comprehensive lens to understand how technological, organizational, and environmental factors shape ICT integration within the tax system and

influence economic growth and fiscal outcomes. The Technology dimension of the TOE framework focuses on infrastructure and digital tools such as broadband, internet services, and evolving connectivity phases that facilitate tax administration through e-filing, online payments, and digital tax platforms. Advanced internet technologies enhance system reliability, reduce fraud, improve compliance, and increase revenue (Aker & Mbiti, 2010; Bennett & Kwakwa, 2017). Thus, internet connectivity moderates the impact of ICT adoption on tax revenue, as Adegboye et al. (2022) show that ICT effectiveness depends on reaching certain penetration thresholds.

The organizational dimension highlights the Tanzania Revenue Authority's (TRA) capacity to adopt and manage ICT systems. Factors such as financial resources, skilled staff, administrative competence, and organizational culture are essential (Zhu et al., 2006). Internal leadership and external support play critical roles in successful implementation, streamlining processes and improving revenue collection (Beynon-Davies, 2009). The environmental dimension includes external conditions like government policy, regulations, and macroeconomic factors. In this context, economic growth is a key environmental variable. ICT adoption enhances productivity, which expands the tax base and boosts revenue (Bryan & Zuva, 2021). Consequently, economic growth is modelled as a mediator between ICT and tax revenue.

Production Theory complements TOE by viewing ICT as a productive input. It improves tax administration through automation, reduced costs, and enhanced compliance monitoring (Mallick, 2021). These efficiencies stimulate economic activity, broadening the tax base and increasing revenue (Sawng et al., 2021). By integrating TOE and Production Theory, this study provides a nuanced view of how ICT drives fiscal performance. It underscores that successful ICT adoption requires not only technological availability but also institutional readiness and alignment with broader economic goals.

Empirical Literature Review and Hypotheses Development

ICT investments are crucial for enhancing the efficiency of tax administration and collection. Bhattacherjee et al. (2024) argue that ICT investments in tax systems increase tax compliance and reduce evasion, leading to higher tax revenue. Their study in Ghana demonstrated that the implementation of e-taxation systems improved tax collection efficiency, which resulted in higher government revenue. Similarly, Bryan and Zuva (2021) highlighted the role of ICT in improving tax systems, stating that technology in tax administration reduces administrative costs and enhances revenue collection by simplifying tax reporting and payment processes.

H_{1a}: ICT investment has a direct influence on tax revenue.

The direct impact of ICT imports on tax revenue is debated. Ekperiware and Adepoju (2013) discuss how ICT imports can stimulate economic growth by fostering innovation and technology transfer. They suggest that ICT imports enhance business efficiency and productivity, which could lead to higher tax revenue through increased business activity. However, Nzepang et al. (2022) caution that high tariffs on ICT imports might hinder their adoption, which could limit the potential economic growth and tax revenue that might result from improved technology adoption. Despite this, studies such as those by Owolabi (2023), argue that when ICT imports are optimized, they can significantly boost economic output and,

by extension, tax revenue.

H_{2a}: ICT imports have a direct influence on tax revenue.

The relationship between internet usage and tax revenue has mixed findings. According to Lowry (2019), internet usage can directly influence tax revenue by enabling the collection of new forms of taxes such as digital services taxes (DST) on online transactions. Moreover, the increased participation in e-commerce and freelancing has created new taxable activities, such as income taxes and VAT on digital goods and services. On the other hand, Zucman (2015), Asmara et al. (2020) and Mambi (2010) argue that internet usage can lead to informal economic activities that escape tax collection, thus reducing formal tax revenue. However, internet usage still plays a significant role in enhancing the tax base in many economies, particularly through online transactions and digital business activities.

H_{3a}: Internet usage has a direct influence on tax revenue.

Broadband penetration improves access to digital platforms for businesses and consumers, which facilitates greater participation in the formal economy. Katz (2018) emphasizes that broadband enables individuals and firms to engage in online activities that lead to new revenue streams, such as online business activities and remote work. Qiang et al. (2009) and Stephens et al. (2022) argue that broadband penetration boosts economic growth by enhancing productivity and facilitating the digital transformation of businesses, which ultimately contributes to tax revenue. Moreover, Pushkareva (2021) indicates that broadband access is essential for modernizing tax administration systems, leading to more efficient tax collection.

H_{4a}: Broadband penetration has a direct influence on tax revenue.

The Moderation Effect of Internet Connectivity Phases

The relationship between ICT adoption and tax revenue is influenced by several factors, one of the most significant being the availability of internet technologies such as 2G, 3G, 4G, and 5G. These technologies can moderate the effectiveness of ICT adoption by enhancing the speed, accessibility, and reach of digital tax services (Calderon & Serven, 2010). Mobile internet technologies such as 2G, 3G, 4G, and 5G play a crucial role in moderating the relationship between ICT adoption and tax revenue. These technologies facilitate more efficient e-government services, such as e-filing, e-receipts, and e-tax payments, which directly impact tax revenue by increasing compliance and reducing tax evasion (Bertot et al., 2010).

Previous studies show that the introduction of 2G, 3G and 4G networks has a significant impact on economic growth by providing faster and more reliable internet access, which facilitates digital government services (Zhang et al., 2015). The availability of these technologies enables smoother digital transactions, leading to more efficient tax collection processes and improved revenue generation (Eden, L., & Rainer, G. 2020). While still in its early stages of implementation, 5G technology is expected to have a stronger moderation effect (Zhao & Su, 2022). By offering ultra-fast data transfer speeds, 5G can enhance the efficiency of tax-related services, such as automated tax reporting and payments, enabling governments to increase revenue collection even further (Li et al., 2020). Broadband ensures that taxpayers can engage in digital tax systems efficiently and quickly, and Internet Usage demonstrates the actual engagement with these systems (World Bank. 2016; OECD. 2020). Therefore, both

variables are more critical in moderating the link between ICT adoption and tax revenue. The following hypotheses was proposed:

H_{1b}: The impact of broadband Penetration on tax revenue is moderated by the presence of Internet Connectivity Phases

H_{2b}: The impact of Internet Usage on tax revenue is moderated by the presence of Internet Connectivity Phases

Mediation Effects of Economic Growth:

Economic growth plays a key role in mediating the relationship between ICT investments and tax revenue. Vu et al. (2020) argue that ICT investments directly stimulate economic growth by improving productivity across various sectors, including manufacturing, services, and agriculture. This growth leads to increased incomes and business profits, which expand the tax base and increase tax revenue. Similarly, Adegbite et al. (2019) found that ICT investment in tax administration systems promotes economic growth by improving the business climate, encouraging private investment, and reducing the cost of doing business, which in turn boosts tax revenue.

H_{1c}: Economic growth mediates the relationship between ICT investment and tax revenue.

Batool et al. (2021) suggest that ICT imports promote innovation and facilitate economic expansion, which indirectly enhances tax revenue by increasing taxable activities. The increased productivity resulting from the adoption of imported technologies fosters economic growth, leading to a broader tax base. Nguyen and Pham (2020) further support this by noting that ICT imports stimulate productivity in key sectors such as agriculture and manufacturing, contributing to higher economic growth, which mediates the relationship between ICT imports and tax revenue. However, Teltscher (2001) notes that barriers to ICT imports, such as high tariffs, could limit their potential to drive economic growth and, consequently, tax revenue.

H_{2c}: Economic growth mediates the relationship between ICT imports and tax revenue.

Internet usage generates new economic activities, such as e-commerce and digital services, that contribute to economic growth. Scharff & Shanske (2022) found that increased internet usage encourages entrepreneurship, particularly in the gig economy, which stimulates economic growth. This growth leads to higher tax revenue through corporate income taxes, consumption taxes, and digital service taxes (DST). Asmara et al. (2020) argue that the digital economy, driven by internet usage, significantly contributes to GDP growth, which in turn affects tax revenue by increasing the taxable base. However, they also warn that informal online activities might reduce tax compliance, highlighting the need for proper regulation and enforcement.

H_{3c}: Economic growth mediates the relationship between internet usage and tax revenue.

Broadband penetration enhances economic growth by improving communication, productivity, and access to digital markets. Zhang et al. (2022) argue that broadband facilitates the growth of digital enterprises, which creates new tax revenue opportunities through corporate and consumption taxes. Moreover, Pushkareva (2021) suggests that broadband

penetration enables the digitalization of tax administration systems, leading to improved tax compliance and increased tax revenue. This economic growth, fuelled by broadband access, mediates the relationship between broadband penetration and tax revenue by expanding the formal economy and increasing business and consumption taxes.

H_{4c}: Economic growth mediates the relationship between broadband penetration and tax revenue.

Conceptual Framework

Figure 1 presents the conceptual framework, showing how ICT adoption influences tax revenue, moderated by internet connectivity phases and mediated by economic growth.

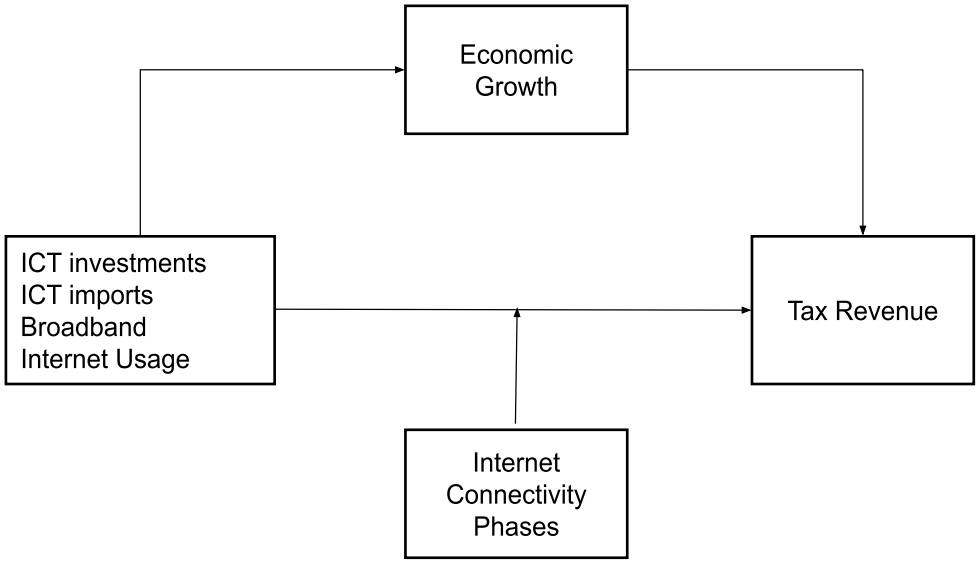

Figure 1: The Conceptual Framework

Methodology

Research Design and Data Collection

Given the study's emphasis on observable and measurable outcomes, a positivist research philosophy was adopted, aligning with Saunders et al. (2009). A deductive research approach was employed, beginning with theoretical assumptions and existing hypotheses, which were then tested using empirical data. The study utilized a time series analysis design to examine the impact of ICT adoption on tax revenue over time, allowing for both trend observation and causal inference. Time series analysis is especially useful for uncovering long-term patterns and forecasting future outcomes (Hudson et al., 2019). The analysis covered data from 1998 to 2022, a 25-year span that captures key technological transitions and policy reforms in Tanzania. Key variables included tax revenue, ICT investment, ICT imports, broadband penetration, and internet usage, with data sourced from the Tanzania Revenue Authority, World Bank, and National Bureau of Statistics. The ARDL model was selected due to its effectiveness in small-sample contexts and its ability to handle variables with different lag lengths. Variable definitions and sources are detailed in Table 1.

Table 1: Operationalization of Variables

Variable	Dimensions/ Indicators	Indicative measures elaborations	Source
Tax Revenue	Total tax revenue	Revenue generated from various types of taxes in a particular country (Justice Iddrisu, 2023)	TRA
ICT investment	Investment cost on ICT items	Government or private sector spending on ICT infrastructure (hardware, software, services) (Bryan & Zuva, 2021)	TRA
ICT import	ICT goods imports (% total goods imports)	Value of ICT goods imported divided by total imports, expressed as a percentage (ITU, 2016)	WBI
Internet Usage	Individual using Internet (%of population)	The % of individuals within a certain population that use the internet (Eden & Rainer,2020)	WBI
Broadband Penetration	Broadband subscriptions (per 100 people)	High-speed internet connectivity enables quick data transmission (katz, 2018)	WBI
Economic growth	Gross Domestic Product (GDP)	The aggregate earnings of a nation's inhabitants during a designated timeframe (Mallick (2021)	NBS

Data Analysis Models

The numerical data underwent several statistical procedures to summarise, organise, and test the final conclusions, as hypothesized in the study. The ARDL, Regressions and Structural Equation Models were implemented using Stata 14 software.

Moderation Effect

To analyze the effects of different advanced internet technologies on the dependent variable, Total Tax, interaction terms were incorporated into the regression models. This approach allowed for the assessment of how the impact of each independent variable differs depending on the phase of internet connectivity (2G, 3G, or 4G). Specifically, as shown in equation 1, we included interaction terms between the independent variables and the phases of internet technology. The model sought to identify whether the relationship between independent variables, and tax revenue was stronger or weaker during specific phases of internet technology.

$$TR_t = a_0 + b_1 BRD_t + c_1 INT_t + d_1 GDP_t + e_1(BRD_t \times 2G) + g_1(BRD_t \times 4G) + e_1(INT_t \times 2G) + h_1(INT_t \times 2G) + i_1(INT_t \times 3G) + j_1(INT_t \times 4G) + U_t \quad (1)$$

Where TR is Tax Revenue, INT, BRD and GDP represents Internet Usage, Broadband penetration and Economic Growth respectively. $(BRD_t \times 2G)$, $(BRD_t \times 3G)(BRD_t \times 4G)$ Represent interaction terms to capture moderation effects

Estimation of Long-term impact

This study uses the ARDL model to examine ICT's impact on tax revenue over a 25-year period. ARDL is ideal for small samples and handles variables integrated at different levels (Pesaran, Shin, & Smith, 2001). It allows analysis of both short- and long-run effects without losing observations through differencing (Shrestha & Bhatta, 2018; Nkoro & Uko, 2016). Equation 2 outlines the ARDL model developed for this study.

$$TR_t = a_0 + \sum_{i=1}^{p} b_i \Delta TR_{t-i} + \sum_{i=1}^{p} c_i \Delta INV_{t-i} + \sum_{i=1}^{p} d\Delta IMP_{t-1} + \sum_{i=1}^{p} e_i \Delta INT_{t-i} + \sum_{i=1}^{p} f_i \Delta BRD_{t-i} + \sum_{i=1}^{p} g_i \Delta GDP_{t-i} + \lambda_1 TR_{t-1} + \lambda_2 INV_{t-1} + \lambda_3 IMP_{t-1} + \lambda_4 INT_{t-1} + \lambda_5 BRD_{t-1} + \lambda_6 GDP_{t-1} + U_t \quad (2)$$

Where IMP=ICT imports, INV=ICT investments and i are indices of lags; $i = 1,2 \ldots . p, p$ is the optimum lag length, t denotes the time periods $t = 1,2 \ldots .., T$ and U_t is the error term. λ's represents the long-run dynamics of the variables. The cointegration can be established when λ is not equal to zero for the level variable in equation 2 above and F-test is used to test the joint significance of lag level variables.

Estimation of Short-term dynamics

An error correction term (ECT) in equation (3) captures these short-run modifications and provides significant information regarding long-run equilibrium changes:

$$TR_t = a_0 + \sum_{i=1}^{p} b_i \Delta TR_{t-i} + \sum_{i=1}^{p} c_i \Delta INV_{t-i} + \sum_{i=1}^{p} d\Delta IMP_{t-1} + \sum_{i=1}^{p} e_i \Delta INT_{t-i} + \sum_{i=1}^{p} f_i \Delta BRD_{t-i} + \sum_{i=1}^{p} g_i \Delta GDP_{t-i} + Au_{t-i} + v_t \ldots\ldots (3)$$

The coefficients $a_i to g_i$ capture the short-run dynamics, with Δ showing how changes in independent variables affect the dependent variable TR in the short term. p represents the optimal lag length based on the Akaike information criterion(AIC). The term Au_{t-i} capture the error correction term, is typically derived from long term relationship between variables in the model. This term adjusts for any disequilibrium in the long run relationship between TR and the independent variables. The coefficient A measures the speed at which the system recovers to equilibrium after a shock.v_t is the white noise error term, representing random shocks or error not explained by the model.

Mediation Analysis

This study performs the mediation analysis utilizing the Structural Equation Modelling (SEM), based on the framework developed by Baron and Kenny (1986). The approach has been fundamental in understanding how a mediator variable transfers the impact of an independent variable to a dependent variable. SEM improves this approach by enabling more complicated models and offering more flexible estimates of direct and indirect effects. Using SEM, the Baron and Kenny approach can be integrated into the mediation analysis as follows:

Direct effect, establish that the independent variable (X) affects the dependent variable (Y)

$$Y = v + cX + e_1 \ldots\ldots (4)$$

c, represents the total effects of X on Y

Path from X to Mediator(M), show that the independent variable(X) affects the Mediator(M)

$$M = v + aX + e_2 \ldots\ldots (5)$$

a, represents the effect of X on M

Path from M to Y, show that the mediator(M) affects the dependent variable(Y), while controlling for the independent variable (X)

$$Y = v + c'X + bM + e_3 \ldots\ldots (6)$$

b, represents the effect of M on Y when X is included in the model

c', represents the effect of M on Y when Mis included in the model.

Assessed the mediation by determine if the effect of X on Y is reduced when M is included in the model, and test the significance of the indirect effect (a*b). Test coefficient c' of equation (6), If c' is significant, the mediated effect is partial; otherwise, it is complete. In this study four digital adoption indicator variables are independent variables (X), one economic growth indicator variable is mediating variables (M), and one total tax revenue indicator variable is

dependent variable (Y). e_1, e_2, and e_3 are residuals. The significance of the indirect effect was assessed using the delta, Sobel, and Monte Carlo simulation tests.

Analysis and Presentation of Findings

Trend Analysis of variable

A critical aspect of this study involved conducting a trend analysis to understand how key variables evolved over time, particularly during periods of technological advancement, as illustrated in Figure 2. Time series plots were generated for Total tax, ICT investment, ICT import, Broadband, and Internet Usage. The analysis revealed a notable increase in ICT investment beginning in the early 2010s and accelerating after 2015, aligning with the government's intensified efforts to digitalize public services. This surge was accompanied by a significant rise in total tax, likely influenced by the implementation of digital tax systems such as e-filing, e-tax payments, and e-receipts introduced by the Tanzania Revenue Authority (TRA). Simultaneously, internet usage saw considerable growth, particularly in urban centres, and broadband increased steadily across the country. The convergence of these developments; rising ICT investment, improved broadband penetration, and growing internet access coincided with a sharp upturn in economic growth and tax revenue collection. This suggests that technological advancement played a central role in enhancing tax compliance and administrative efficiency. Overall, the trend analysis highlights the transformative impact of ICT adoption on fiscal performance in Tanzania, especially after 2015.

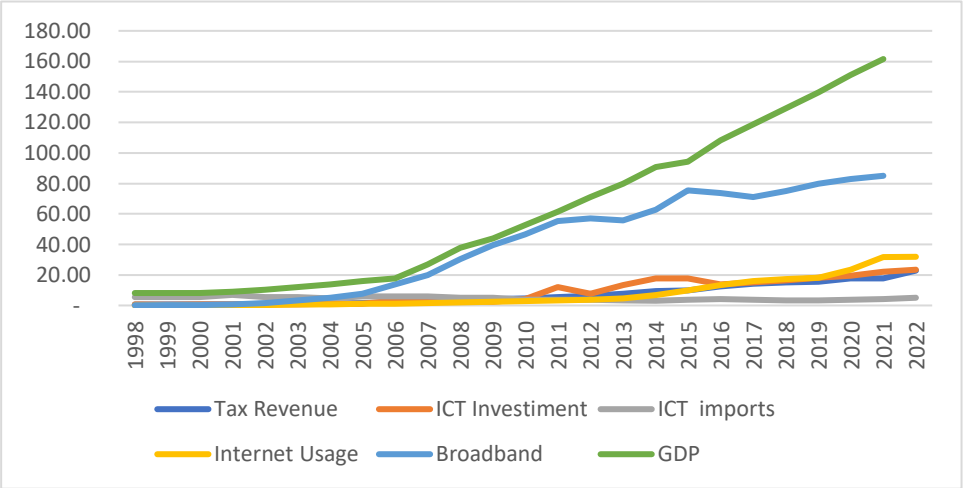

Figure 2: Trend Analysis

Source: *Authors own work*

Unit root test

Table 2 presents results from the Augmented Dickey-Fuller (ADF) test, assessing unit root presence. This parametric test considers error term correlation (Afzal et al., 2010). Insignificant ADF statistics suggest a unit root ($p > 0.05$). Only two variables were stationary at level, and four became stationary at first difference. Given the presence of unit roots in most variables, first differencing was applied to ensure stationarity before modelling, avoiding spurious regression.

Table 2: Unit Root Tests

Variable	ADF				Decision
	At level		At First difference		
	Include Trend	Include Drift	Include Trend	Include Drift	
Tax Revenue	0.9952	0.0715	0.4564	0.0466	(1)
ICT Investment	0.6738	0.2184	0.0016	0.0001	(1)
ICT imports	0.1865	0.1644	0.0126	0.0004	(1)
Internet usage	0.0000	0.0001	0.0002	0.0000	(0)
Broadband penetration	0.8575	0.0076	0.0063	0.0037	(0)
GDP	0.876	0.1127	0.4173	0.0229	(1)

Source: Authors own work

Multicollinearity test

The Variance Inflation Factor (VIF) results in Table 3 indicate no serious multicollinearity among the independent variables, as all VIF values are well below the common threshold of 10. The mean VIF of 1.33 further confirms low correlation between predictors. This suggests that the estimates in the regression model are stable and reliable, and multicollinearity is unlikely to distort the interpretation of the individual variable effects

Table 3: Multicollinearity test

Variable	VIF	1/VIF
Broadband Penetration	1.67	0.597820
ICT investment	1.24	0.808243
GDP	1.22	0.820344
Internet usage	1.21	0.828613
ICT imports	1.17	0.854348
Mean VIF	1.33	

Source: Authors own work

Diagnostic Tests

These tests validate the model's suitability and robustness in capturing long-term relationships. The Breusch-Godfrey test results in Table 4, show p-values of 0.9404, indicating no significant autocorrelation, confirming accurate parameter estimations. The CUSUM and CUSUM of squares (CUSUMQ) tests in Figure 3; indicate parameter stability, as plots remain within boundary limits, supporting long-term stability of tax revenue function coefficients in both ARDL and Error Correction Models.

Table 4: Breusch-Godfrey LM test for autocorrelation

lags(p)	chi2	df	Prob> chi2
1	0.006	1	0.9404

Ho: no serial correlation

Source: Authors own work

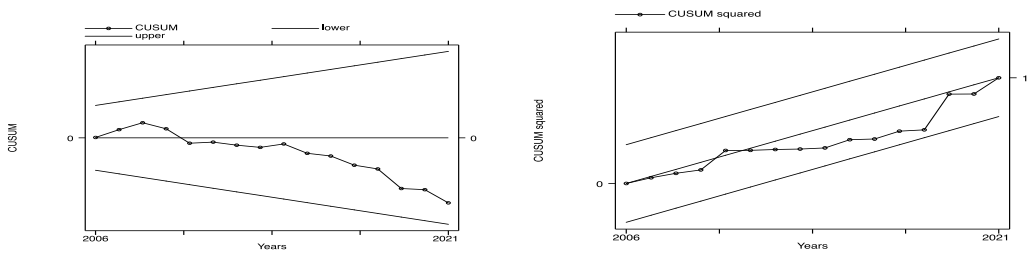

Figure 3: CUSUM and CUSUMQ Test

Table 5: The Moderation effect of Internet Connectivity Phases

	SS	df	MS	Number of obs	25
				F(12, 12)	1686.79
Model	36.2516244	12	3.021183	Prob > F	0.0000
Residual	0.021493	12	0.001791	R-squared	0.9993
Total	36.2756935	24	1.511487	Adj R-squared	0.9989
				Root MSE	0.04146

Total Tax	Coef	Sta.Err.	t	P	[95% Conf.	Interval]
Internet Usage	0.0731445	0.114025	0.82	0.139	-0.1552946	1.50922
Broadband	0.2229352	0.158224	1.41	0.084	-0.1218052	0.5676756
GDP	1.196493	0.1704484	7.02	0.000	0.8251178	1.567868
phase_2G	-1.098189	0.5207362	-2.11	0.057	-2.232776	0.0363974
phase_3G	-0.9783743	0.4542543	-2.15	0.052	-1.968109	0.0113609
phase_4G	-0.9244659	0.5023088	-1.84	0.031	-2.018903	0.1699709
Interact _2G_internet	-0.122223	0.1024857	-1.19	0.256	-0.3455201	0.1010741
Interact _3G_internet	0.0528777	0.0518076	1.02	0.328	-0.0600013	0.1657567
Interact _4G_internet	0.03101	0.0683459	0.45	0.658	-0.1179029	0.1799228
Interact _2G_Broadband	0.0071452	0.1733895	0.04	0.068	0.3849285	0.370638
Interact _3G_Broadband	0.0454482	0.0762813	0.6	0.042	0.2116509	0.1207545
Interact _4G_Broadband	0.039615	0.1761676	0.22	0.026	0.3442212	0.4234512
_cons	2.478885	0.4450429	5.57	0.000	1.50922	3.44855

Source: Authors own work

Moderation Effect of Internet Connectivity Phases

Table 5 supports H_{1b} but not H_{2b}. Broadband combined with 3G and 4G strengthens the link between ICT adoption and tax revenue. However, internet usage alone does not show a moderating effect, indicating it has limited influence without broadband support.

Long-term Relationship and Mediation Analysis

After confirming mixed integration orders among the variables, the ARDL bounds test was conducted, as presented in Table 6. The resulting F-statistic (7.988) exceeded all the critical value bounds, indicating the presence of cointegration. This result established the foundation for estimating both the long-run relationship and the short-term dynamics among the variables.

Table 6: ARDL Bound F-Test

Test Statistics	Value	Significance	Lower Bound	Upper Bound
F-statistics	7.988	10%	2.26	3.35
		5%	2.62	3.79
		2.5%	2.69	4.18
		1%	3.41	4.68

Source: Authors own work

Estimation of Longrun Impact and Shorterm Dynamics

The ARDL model in Table 7 demonstrates significant long-term positive effects of ICT investment, ICT imports, broadband penetration, and GDP on tax revenue, indicating sustained benefits from digital infrastructure and economic growth. In the short term, however, the dynamic effects are mixed, with negative adjustments suggesting initial implementation challenges or delayed impacts of ICT-related investments.

ICT investment, GDP and Tax revenue

Table 7 shows ICT investment has a positive long-term impact on tax revenue, supporting H_{1a}. However, short-term and lagged effects are negative, likely due to upfront costs. Table 8 confirms GDP partially mediates this relationship, with 75% of the effect channelled through GDP, and the mediated effect being three times the direct effect.

Table 7: ARDL Model Estimation

ARDL (1,2,2,0,2,1) regression

Sample: 1998 - 2022						Number of obs	23
						R-squared	0.905
						Adj R-squared	0.7678
Log likelihood = 55.196855						Root MSE	0.0351
	D.lnTotalTax	Coef	Sta.Err.	t	P	[95% Conf.	Interval]
ADJ	Total Tax						
	L1	-1.058092	0.1937	-5.46	0	-1.496272	-0.6199127
LR	ICT investment	0.151229	0.060107	2.52	0.033	0.0152585	0.2871995
	ICT imports	0.3558966	0.126204	2.82	0.02	0.0704039	0.6413893
	Internet Usage	-0.1187787	0.0415	-2.86	0.019	-0.2126587	-0.0248987
	Broadband	0.3608458	0.101424	3.56	0.006	0.1314082	0.5902833
	GDP	1.421795	0.165981	8.57	0	1.046319	1.797271
SR	ICT investment						
	D1.	-0.1298516	0.050578	-2.57	0.03	-0.2442679	-0.0154354
	LD.	-0.0741788	0.035558	-2.09	0.067	-0.1546173	0.0062596
	ICT imports						
	D1.	-0.2844153	0.115124	-2.47	0.036	-0.5448427	-0.0239879
	LD.	-0.1471554	0.093818	-1.57	0.151	-0.3593856	0.0650748
	Broadband						
	D1.	-0.2911917	0.113633	-2.56	0.031	-0.5482482	-0.0341353
	LD.	-0.25822	0.077652	-3.33	0.009	-0.4338817	-0.0825582
	GDP						
	D1.	-1.117075	0.433378	-2.58	0.03	-2.097444	-0.1367066
	_cons	1.42549	0.399388	3.57	0.006	0.5220107	2.328969

Source: Authors own work

Table 8: The Mediation of GDP on ICT investment and Total tax revenue

Estimates	Delta	Sobel	Monte Carlo
Indirect effect	0.621	0.621	0.625
Std. Err.	0.08	0.08	0.08
z-value	7.759	7.759	7.812
p-value	0.000	0.000	0.000
Conf. Interval	0.464 , 0.778	0.464 , 0.778	0.459 , 0.780
Baron and Kenny approach to testing mediation			
STEP 1 - GDP: ICT investment (X -> M) with B=0.563 and p=0.000			
STEP 2 - Total Tax: lGDP (M -> Y) with B=1.104 and p=0.000			
STEP 3 - Total Tax: ICT investment (X -> Y) with B=0.207 and p=0.007			
As STEP 1, STEP 2 and STEP 3 as well as the Sobel's test above			
are significant the mediation is partial!			
RIT = (Indirect effect / Total effect)			
(0.621 / 0.828) = 0.750			
Meaning that about 75 % of the effect of ICT investment			
on lnTotalTax is mediated by lnGDP!			
RID = (Indirect effect / Direct effect)			
(0.621 / 0.207) = 3.002			
That is, the mediated effect is about 3.0 times as			
large as the direct effect of ICT investment on Total Tax.			

Source: Authors own work

ICT import, GDP and Tax revenue

Table 7 shows that ICT imports significantly increase tax revenue in the long term, supporting H_{2a}. However, mediation analysis in Table 9 reveals GDP fully mediates this relationship, with 93% of the effect channelled through GDP. Although ICT imports negatively affect GDP, GDP's strong positive impact on tax revenue results in a large mediated effect, supporting H_{2c}.

Internet Usage, GDP and Tax revenue

Table 7 shows that long-term internet usage has a significant negative effect on tax revenue, disproving H_{3a}. However, mediation analysis in Table 10 reveals that GDP fully mediates this relationship. Internet usage positively impacts GDP, which then boosts tax revenue. The indirect effect accounts for 89.2% of internet usage's impact on tax revenue, supporting H_{3c}.

Broadband Penetration, GDP and Total tax revenue

Table 7 shows broadband penetration significantly increases tax revenue over time, supporting H_{4a}. Mediation analysis in Table 11 confirms GDP fully mediates this relationship. Broadband boosts GDP, which in turn raises tax revenue. The indirect effect accounts for 96% of the impact, supporting H_{4c}.

Table 9: The Mediation of GDP on ICT import and Total tax revenue

Estimates	Delta	Sobel	Monte Carlo
Indirect effect	-4.002	-4.002	-4.046
Std. Err.	0.529	0.529	0.523
z-value	-7.559	-7.559	-7.733
p-value	0.000	0.000	0.000
Conf. Interval	-5039, -2.964	-5039, -2.964	-5093, -3.015
Baron and Kenny approach to testing mediation			
STEP 1 - GDP: ICT imports (X -> M) with B=-2.933 and p=0.000			
STEP 2 - Total Tax: GDP (M -> Y) with B=1.374 and p=0.000			
STEP 3 - Total Tax: ICT imports (X -> Y) with B=0.314 and p=0.159			
As STEP 1, STEP 2 and the Sobel's test above			
are significant and STEP 3 is not significant the mediation is complete.			
RIT = (Indirect effect / Total effect)			
(4.002 / 4.315) = 0.927			
Meaning that about 93 % of the effect of ICT imports			
on Total Tax is mediated by GDP			
RID = (Indirect effect / Direct effect)			
(4.002 / 0.314) = 12.764			
That is, the mediated effect is about 12.8 times as			
large as the direct effect of ICT imports on Total Tax.			

Source: Authors own work

Table 10: The Mediation of GDP on Internet usage and Total tax revenue

Estimates	Delta	Sobel	Monte Carlo
Indirect effect	0.577	0.577	0.578
Std. Err.	0.055	0.055	0.056
z-value	10.412	10.412	10.366
p-value	0.000	0.000	0.000
Conf. Interval	0.468, 0.686	0.468, 0.686	0.465, 0.682
Baron and Kenny approach to testing mediation			
STEP 1 - GDP: Internet Usage (X -> M) with β=0.353 and p=0.000			
STEP 2 - Total Tax: GDP (M -> Y) with β=1.636 and p=0.000			
STEP 3 - Total Tax: Internet Usage (X -> Y) with β=0.070 and p=0.139			
As STEP 1, STEP 2 and the Sobel's test above			
are significant and STEP 3 is not significant the mediation is complete			
RIT = (Indirect effect / Total effect)			
(0577 / 0.647) =0.892			
Meaning that about 89.2 % of the effect of internet Usage			
on Total Tax is mediated by GDP			
RID = (Indirect effect / Direct effect)			
(0.577 / 0.070) = 8.250			
That is, the mediated effect is about 8.2 times as			
large as the direct effect of internet usage on Total Tax.			

Source: Authors own work

Table 11: The Mediation of GDP on Broadband penetration and Total tax revenue

Estimates	Delta	Sobel	Monte Carlo
Indirect effect	2.294	2.294	2.287
Std. Err.	0.273	0.273	0.276
z-value	8.417	8.417	8.288
p-value	0.000	0.000	0.000
Conf. Interval	1.760, 2.828	1.760, 2.828	1.761, 2.837
Baron and Kenny approach to testing mediation			
STEP 1 - GDP: Broadband penetration (X -> M) with B=1.632 and p=0.000			
STEP 2 - Total Tax: GDP (M -> Y) with B=1.405 and p=0.000			
STEP 3 - Total Tax: broadband penetration (X -> Y) with B=0.096 and p=0.087			
As STEP 1, STEP 2 and the Sobel's test above			
are significant and STEP 3 is not significant the mediation is complete			
RIT = (Indirect effect / Total effect)			
(2.294 / 2.390) =0.960			
Meaning that about 96 % of the effect of broadband penetration			
on Total Tax is mediated by GDP			
RID = (Indirect effect / Direct effect)			
(2.294 / 0.087) = 23.822			
That is, the mediated effect is about 23.8 times as			
large as the direct effect of broadband penetration on Total Tax.			

Source: Authors own work

Discussion of Findings

Long-term relationship and Mediation by Economic Growth

ICT Investment and Tax Revenue

The findings confirm that ICT investment significantly enhances tax revenue in the long run, supporting Hypothesis H_{1a}. Table 7 shows that a one-unit increase in ICT investment is associated with a 0.151-unit rise in tax revenue, affirming previous research that links digital infrastructure to improved administrative efficiency and economic performance (Bhattacherjee et al. 2024; Bryan and Zuva, 2021). However, the short-term impact is negative, and the lagged effect also shows a modest decline. This suggests that initial ICT investments may reduce tax revenue due to setup costs, implementation lags, and adjustment periods, findings consistent with Olaoye and Atilola (2018) and Mallick (2021), who observed similar dynamics in Nigeria and India. GDP partially mediates the relationship between ICT investment and tax revenue, supporting Hypothesis H_{1c}. As shown in Table 8, the indirect effect accounts for approximately 75% of the total effect, with the mediated effect being three times larger than the direct effect. This reinforces the Production Theory perspective, where ICT operates as a productive input that indirectly boosts tax collection by enhancing GDP. Furthermore, the TOE framework suggests that without proper organizational readiness and a supportive policy environment, the long-term fiscal benefits of ICT investment may remain underutilized.

ICT Imports and Tax Revenue

ICT imports show a significant long-term positive impact on tax revenue, supporting both Hypotheses H_{2a} and H_{2c}. As shown in Table 7, each unit increase in ICT imports leads to a 0.36-unit rise in tax revenue, consistent with studies by Ekperiware and Adepoju (2013) and Owolabi (2023), who highlight how imported technologies enhance productivity by supplementing domestic capabilities. However, the mediation analysis in Table 9 reveals that this effect is almost entirely indirect. Despite their negative direct effect on GDP, ICT imports indirectly enhance tax revenue through GDP, which mediates 93% of the total impact. With regards to TOE framework, ICT imports expand the technological base, but their fiscal effectiveness depends on organizational readiness and supportive policy environments. Without complementary efforts such as training, systems integration, and regulatory alignment imported technologies may remain underutilized. Moreover, international standards on digital trade and data governance can shape the usability of these technologies. Ultimately, ICT imports play a transformative, albeit indirect, role in enhancing digital tax infrastructure and revenue generation.

Internet Usage and Tax Revenue

The relationship between internet usage and tax revenue presents a paradoxical dynamic. Empirically, the model shows a significant negative direct effect of internet usage on tax revenue, contradicting Hypothesis H_{3a}. This suggests that a 1% increase in the share of individuals using the internet is associated with a 12% decrease in total tax income. This finding aligns with concerns raised by Zucman (2015) and Asmara et al. (2020), who argue that increased internet penetration especially in unregulated digital sectors can erode the tax base by enabling cross-border transactions, informal e-commerce, and tax evasion. However, caution is warranted in interpreting this result as causal. The negative association may reflect endogeneity or omitted variable bias, such as institutional weakness in regions with high internet use, where tax enforcement is already low (Mambi 2010). As Ting and Gray (2019) highlight, without regulatory reforms and enforcement mechanisms, internet expansion can outpace the fiscal system's capacity to capture digital economic activity. Nevertheless, the mediation analysis offers a more nuanced perspective. GDP fully mediates this relationship, internet usage significantly increases economic growth, which in turn boosts tax revenue. This supports Hypothesis H_{3c} and resonates with Production Theory, were internet usage acts as a productive input fuelling economic activity. This also reflects the TOE framework**,** without supportive organizational capacity and an enabling regulatory environment, the fiscal potential of digital connectivity remains constrained.

Broadband Penetration and Tax Revenue

Broadband penetration exhibits a strong long-term impact on tax revenue, though this effect operates primarily through GDP rather than directly supporting Hypotheses H_{4a} and H_{4c}. As shown in Table 7, a 1% increase in broadband penetration corresponds to a 36% increase in tax revenue. However, the mediation analysis in Table 11 confirms that 96% of this effect is channeled through GDP, with broadband significantly boosting economic activity, which in turn raises tax revenue. The indirect effect is 23.8 times larger than the direct effect. These findings align with the broader literature (Stephens et al., 2022; Pushkareva, 2021), which sees

broadband less as a direct tax-enhancing tool and more as a foundational enabler of productivity, communication, and market efficiency. This reinforces both the TOE framework and Production Theory: broadband represents the "technology" component whose fiscal outcomes depend on the presence of "organizational" systems (e.g., digital tax platforms) and conducive "environmental" policies (e.g., national broadband strategies, equitable access). Without institutional readiness or inclusive digital policies, broadband's tax potential may remain unrealized, even in the face of rising connectivity.

Moderating Effect of Internet Connectivity Phases

The moderating effects of 2G, 3G, and 4G connectivity on ICT–tax revenue relationships show that more advanced technologies (particularly 3G and 4G) significantly enhance broadband's fiscal impact. This partially supports Hypothesis H_{1b}. While 2G infrastructure increases basic connectivity, it is insufficient for data-heavy applications such as digital invoicing or AI-powered tax analytics. 3G and 4G, however, allow for real-time transactions and the scaling of automated systems. This supports Qiang et al. (2009) and Li et al. (2020), who emphasized the importance of high-speed networks for public sector modernization. Crucially, the effectiveness of these technologies again depends on organizational and environmental readiness. If tax authorities lack the capacity to manage high-speed digital platforms, or if regulatory gaps persist, allowing firms to operate outside the tax net; the transformative potential of 4G and emerging 5G technologies remains untapped. The TOE framework explains this variation by emphasizing that technology adoption must be context-sensitive, shaped by institutional capability, policy coherence, and infrastructure maturity.

Conclusion and Further Research

This study provides empirical evidence that ICT adoption plays a pivotal role in enhancing domestic resource mobilization in Tanzania, but the relationship is mediated by broader economic activity and moderated by the quality of digital networks. While technologies such as broadband and mobile connectivity contribute positively to tax collection, their impact is not automatic or uniform across indicators. The negative association between Internet usage and tax revenue points to a policy paradox: while digital access is expanding, fiscal institutions have yet to fully integrate the digital economy into their regulatory scope. This calls for targeted reforms to modernize digital tax administration and close compliance loopholes, particularly in e-commerce and informal digital trade. The findings support a more strategic approach to ICT adoption, emphasizing not just access but also depth, reliability, and integration with institutional processes. Policymakers should prioritize high-speed infrastructure (e.g., 4G/5G), invest in digital literacy, and develop real-time tax data systems to capture economic activity in the digital space.

Economic growth serves as a mediating variable between ICT adoption and tax revenue, supporting the broader notion that increased economic activity leads to higher income and consumption, thereby raising tax revenues. This aligns with Production Theory, which views ICT as an input that boosts productivity and enhances tax revenue generation. Furthermore, the TOE framework highlights the necessity of a supportive environment adequate infrastructure, organizational resources, and governmental policies for ICT adoption to succeed. Advanced research models such as ARDL and SEM have confirmed the long-term

effects of ICT adoption on economic growth and tax revenue, suggesting future research could expand on these findings by investigating regional variations and examining non-linear models for greater precision. Further exploration of the negative impact of internet usage on tax revenue, especially in light of digital tax avoidance, will also be essential for crafting informed policy strategies. Additionally, research on how internet connectivity and broadband access can be optimized for equitable economic development will provide valuable insights for improving tax revenue generation in developing countries

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