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The Impact of Digital Infrastructure and Human Capital Development on Economic Growth in Burkina Faso

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Abstract

This study aims to analyze the relationship between the development of digital infrastructure and human capital and economic growth in Burkina Faso from 1996 to 2024. This research examines the long run and short run relationships of real GDP per capita with mobile cellular subscriptions, internet use, life expectancy at birth and gross fixed capital formation using a pure time-series Autoregressive Distributed Lag (ARDL) bounds-testing approach. The unit root test result is consistent with all variables being integrated of order one. There is a stable long run cointegration relationship between the series at the 1 percent significance level as suggested by the bounds test. The estimated life expectancy at birth, with individual statistical significance, is a positive determinant of real GDP per capita; the estimated mobile cellular subscriptions and the estimated internet usage and gross fixed capital formation are not individually statistically significant. The error-correction term is negative and significant which suggests that about 50.61 percent of any error from the long-run equilibrium is corrected within one year. The serial correlation and the heteroskedasticity tests from residual data are not evident, and the CUSUM and the CUSUM of Squares are used to check for stability of the parameters. The results point to the critical importance of health-capital accumulation in the economy's growth over time in Burkina Faso and indicate that growth impacts of digital infrastructure might vary depending on the interaction of these omitted factors and the linear specification.

Keywords: Digital infrastructure; Human capital; Life expectancy; Economic growth; ARDL; Burkina Faso; Cointegration; Mobile cellular subscriptions; Internet usage

Introduction

Economic growth remains one of the most fundamental objectives of economic policy in developing countries. A sustained improvement in real output per capita is known to be the most important determinant of the improvement in living standards, reduction of absolute poverty, increased employment opportunities and the fiscal resources required for public investment in infrastructure, education and health [1,2]. In Sub-Saharan Africa, and especially for Sahelian countries, high poverty rates make it particularly difficult to ensure both strong economic growth and sustainable growth. These economies are characterized by multiple structural constraints such as limited physical capital, low human capital, high reliance on rain-fed agriculture, exposure to climatic shocks, low institutional capacity, and geographic disadvantages of land-locked status in many cases [3,4]. Burkina Faso is a case in point in this general landscape. It is a Sahelian land-locked and low-income nation, which has been traditionally dependent on agriculture, gold mining and official development assistance. Growth has been patchy, and often followed by droughts, price volatility for commodities and periods of political unrest. In this context, two potentially game-changers have taken place in the last 30 years. The first is the quick growth of digital infrastructure, particularly mobile cellular networks and, more recently, Internet access. The second is the continuous health gains, most evident in the increase in life expectancy at birth.

Also important is the timeframe that was analyzed (1996-2024). It starts when mobile cellular subscriptions in Burkina Faso were still small and Internet use was nonexistent and continues to the years of rapid mobile penetration and the gradual availability of Internet access as well as the continued improvements in life expectancy. This long span is appropriate for exploring long-term relationships, since it encompasses both the early and later stages of digital diffusion and of accumulation of health-capital. In light of these considerations, the present study investigates the impact of digital infrastructure—measured by mobile cellular subscriptions and individuals using the Internet—and human capital development—measured by life expectancy at birth—on economic growth in Burkina Faso, while controlling for physical capital formation. The analysis utilizes the ARDL bounds-testing methodology suggested by Pesaran, Shin and Smith which is suitable for the small-sample and country-specific time-series context and can simultaneously address long-run equilibrium analysis and short-run adjustment dynamics [5].

Statement of the problem

Burkina Faso has made significant gains in some aspects of development over the last 30 years. The number of mobile cellular subscriptions had increased from close to zero to more than 100 subscriptions per 100 people. Although the use of the Internet remains fairly low in global terms, over the last few years it has grown from a negligible level to over one-quarter of the population. The life expectancy at birth has increased consistently, paralleled by improvements in public health, nutrition and disease prevention. Gross fixed capital formation has been within a fairly narrow range and has been an essential part of aggregate demand and productive capacity. All the above have not succeeded in improving real GDP per capita, which is low by international standards and has increased rather modestly. The seeming mismatch between the growth of digital and health capital and the relatively small increase in average living standards is the major empirical puzzle that propelled the present study.

A number of possible explanations can be put forward. First, the growth effects of digital technologies may be subject to threshold effects: a critical mass of users, complementary infrastructure and skills may be required before significant productivity gains materialize [6]. Second, there is a possibility of digital infrastructure using complementary channels to human capital instead of as a standalone driver [7]. Third, the measurement problem, the multicollinearity of the regressors or the relatively small effective sample size for some of the regressors may mask true long-term relationships. Fourth, structural constraints unique to Burkina Faso, such as the landlocked geography, climatic exposure, security issues, and institutional constraints, can dampen the impact of digital and health gains on sustained growth. Most studies that examine the growth effects of information and communication technology (ICT) or human capital in Africa employ panel techniques that average effects across countries [8,9]. Evidence from country-specific time-series is still limited, especially for the Sahelian economies This study fills this gap by systematically exploring the long run and short run relationships of the study variables between 1996 and 2024 by employing the ARDL method.

Research objectives

The general objective of this study is to examine the impact of digital infrastructure and human capital development on economic growth in Burkina Faso during the period 1996–2024.

The goals of the specific objectives are as follows:

- To investigate the time-series properties of real GDP per capita, mobile cellular subscriptions, internet usage, life expectancy at birth and gross fixed capital formation, and to determine their orders of integration.
- To test for a long run cointegration relationship between these variables using ARDL bounds-testing procedure.
- To estimate the long-run elasticities of real GDP per capita with respect to mobile cellular subscriptions, internet usage, life expectancy at birth and gross fixed capital formation.
- To investigate the short-run nature of the relationship and to estimate the rate of convergence to the long run equilibrium through the error-correction mechanism.
- To check statistical adequacy of the preferred model using all available residual diagnostic tests and to verify stability of estimated parameters using CUSUM and CUSUM of Squares procedures.

These goals aim to progress systematically from data characterization to cointegration testing to estimation of long-run and short-run effects, with a final outcome that is statistically sound.

Research hypotheses

Drawing on the theoretical literature on augmented neoclassical growth, endogenous growth, health capital and general-purpose technologies, the study formulates the following testable hypotheses [10-15]:

- **H1:** There exists a long-run cointegrating relationship among real GDP per capita, mobile cellular subscriptions, internet usage, life expectancy at birth and gross fixed capital formation in Burkina Faso.
- **H2:** Mobile cellular subscriptions exert a positive and statistically significant long-run effect on real GDP per capita.
- **H3:** Internet usage exerts a positive and statistically significant long-run effect on real GDP per capita.
- **H4:** Life expectancy at birth exerts a positive and statistically significant long-run effect on real GDP per capita.
- **H5:** Gross fixed capital formation exerts a positive and statistically significant long-run effect on real GDP per capita.

- **H6:** The error-correction term is negative and statistically significant, indicating that deviations from the long-run equilibrium are systematically corrected over time.

These hypotheses guide the empirical analysis and provide clear criteria for evaluating the results of the bounds test, the long-run coefficient estimates and the error-correction model.

Significance of the study

From an academic perspective, this study contributes to the literature by providing one of the few pure time-series ARDL analyses that jointly examines digital infrastructure and health capital in a Sahelian economy. Previous research mostly uses panel data techniques that make implicit the assumption of slope homogeneity across countries. The single-country approach used here provides estimates which are specific to the structural and historical conditions of Burkina Faso and is consistent with current best practice in applied time-series econometrics. From a practical perspective, the findings offer evidence that can inform the prioritization of development interventions in Burkina Faso. Additionally, a significant long-run impact on life expectancy would support the long-term investment in public health [16]. Limited significance of the digital infrastructure variables would suggest the need for complementary policies such as digital skills development, electricity access and regulatory improvements.

Scope and limitation of the study

This study focuses exclusively on Burkina Faso and covers the period 1996–2024. The analysis looks at the relationship between real GDP per capita and the four explanatory variables used: mobile cellular subscriptions, internet use, life expectancy at birth, and gross fixed capital formation. There is no measure of education indicators. Education indicators are not considered; only life expectancy. The main limitations include the relatively small sample size (approximately 29 annual observations), sparse early data on internet usage that required limited interpolation, possible multicollinearity among the digital and capital variables, and the single-country focus, which limits generalization to other Sahelian economies.

Organization of the study

The rest of the study is divided into four chapters. Chapter 2 summarizes the current theoretical and empirical literature on the subject of digital infrastructure, human capital and economic growth; outlines the key gaps in current analytical literature; and connects the current research with the existing literature. The theoretical framework is then elaborated in chapter 3, the empirical model is defined, the data sources and the definitions of the variables used are explained, and the ARDL bounds-testing procedure and its corresponding diagnostic and stability tests are explained. The results of the empirical analysis are presented in order: descriptive statistics, unit-root tests, lag selection, bounds testing, long-run elasticity, error-correction estimates, residual diagnostics and parameter stability, with detailed interpretation. Chapter 5 provides a summary of the key findings, details the theoretical and empirical contributions of the study, provides policy recommendations, recognizes research limitations and recommends future research.

Definition of key terms

For clarity, the principal terms used throughout the study are defined as follows:

Economic growth is defined as sustained rise in real GDP per capita which is the key indicator of the increase in average living standards and aggregate labour productivity [17].

Digital infrastructure: The physical and organizational systems that enable digital communication and information exchange, proxied in this study by mobile cellular subscriptions per 100 people and the percentage of individuals using the Internet.

Human capital development: Development of knowledge, skills and health of the population which increases labour productivity. Life expectancy at birth is used as an indicator of health capital in this study, and is considered a summary indicator of human capital.

Physical capital formation: Gross fixed capital formation as a percentage of GDP.

Long-run relationship (cointegration): When two non-stationary variables are related in such a way that deviations from the relationship are only short term.

Error correction mechanism: This is a process in which short-run deviations from a long-run cointegrating relationship are gradually eliminated, which is expressed by the coefficient of the lagged error correction term.

These definitions ensure consistency of interpretation across the theoretical, methodological and empirical chapters that follow

Literature Review

Theoretical framework

The augmented neoclassical growth framework

The foundational architecture for analyzing aggregate production dynamics originates from the neoclassical model of Solow and Swan and was later supplemented by Mankiw, Romer, and Weil. The augmented Solow framework relaxes an assumption of purely exogenous technological progress and physical capital accumulation, and allows for the inclusion of human capital (H) as a factor of production separate from physical capital (K) and raw labor (L). The aggregate production function is written as:

$$Y_t = K_t^{\alpha} H_t^{\beta} (A_t L_t)^{1-\alpha-\beta}$$

where it is assumed that α+β < 1 so that the aggregate production function exhibits diminishing returns to the reproducible factor of production, which is the capital stock K. In this context, human capital (including the level of formal education and health capital, measured as a simple aggregate of the health of workers) is a direct contributor of making workers more efficient and of increasing overall output.

Endogenous growth theory and knowledge spillovers

In contrast to the neoclassical convergence prediction is that growth should level off once a certain level of human knowledge is reached, endogenous growth theory and the work of Lucas and Romer suggest that the accumulation of human capital creates positive externalities, which offset the decline in the marginal productivity of capital. Lucas highlights two types of impacts of human capital: the impact of human capital on private productivity, through the investments made by individuals in acquiring skills; and the impact of the human capital stock on the overall efficiency of all production factors in the economy, through the contribution of individual levels of human capital.

The health capital model

Health as a core component of human capital is formally conceptualized by Grossman. Grossman's approach conceptualizes health as a durable capital stock (H_t) producing healthy time as an output. The stock of health capital depreciates over time at rate δt and can be augmented through gross investments (I_t) in healthcare, nutrition, and environmental infrastructure:

$$H_{t+1} = I_t + (1 - \delta_t)H_t$$

Improvement in health outcomes (typically measured by life expectancy at birth) increase overall labor productivity, diminish absenteeism, and extend the economic lives over which people can realize returns on education and skills, leading to increased domestic saving and capital accumulation.

Digital infrastructure as a general-purpose technology (GPT)

The theoretical connection between digital telecommunications infrastructure and aggregate economic performance is based on the General-Purpose Technology (GPT) framework that Bresnahan and Trajtenberg have proposed. Digital infrastructure—optical fiber networks, secure broadband servers, mobile cellular coverage and high-speed Internet access—has three key characteristics:

Pervasiveness: It spreads into virtually all sectors of the economy.

Continuous Improvement: Its cost falls and functionality expand rapidly over time.

Innovational Complementarities: It triggers technical innovations and business model changes downstream.

Digital infrastructure cuts the cost of searching for information, transactional costs, and information asymmetries in markets, thus increasing total factor productivity (TFP). In addition, human capital resources are also connected synergistically with digital connectivity. High speed broadband amplifies the productivity of skilled workers by making it possible to work remotely, access e-learning services, provide financial inclusion through digital banking, and provide the knowledge and information products in real time across regional market centers.

Empirical Literature

Human capital accumulation and economic growth

Empirical measures of human capital are based on two main components: education and health. Mankiw found that differences in GDP per capita across countries are significant and can be accounted for by the rate of educational enrolment and the level of physical capital accumulation. In the developing regions, Donou-Adonsou confirmed that an increase in secondary and tertiary education qualifications leads to a greater absorption of modern technologies, resulting in positive long-term growth effects. With respect to the health aspect, Avci and Caliskan applied the bounds test methodology of Autoregressive Distributed Lag (ARDL) and validated the existence of a positive and statistically significant long-run relationship between life expectancy at birth and GDP performance. Following these results, Sultana examined the effect of life expectancy gains on macroeconomic productivity for a dynamic panel of 141 countries, taking into account the endogeneity of the life expectancy variable, and found that such gains have a lasting positive impact on macroeconomic productivity. Likewise, at the microeconomic level Siri and Combary showed that investments in health and human capital produce non-linear income gains when combined with access to productive physical assets [18].

Digital infrastructure and aggregate productivity

The macroeconomic impacts of digital infrastructure growth have been a wide-ranging area of study that has been assessed in a variety of panel datasets. Donou-Adonsou examined 47 Sub-Saharan African economies by applying dynamic panel estimators and concluded that the growth effect of internet adoption was around four times stronger than the growth effect of mobile cellular adoption, because of its wider usage in business automation. Calderon and Cantu established that the effects of digital infrastructure on aggregate output are mediated by two main channels: mobile connectivity primarily through TFP productivity gains, and broadband Internet primarily through the process of capital accumulation and structural change. Empirical studies of the past few years have pointed to the threshold effects and structural complementarities of digital infrastructure investments. Dah applied a System GMM estimator to African panel data from

2000 to 2021, revealing a non-linear interaction between human capital and the digital economy. Their research shows that a minimum level of human capital is required for a successful outcome of digital investments in terms of sustainable growth of the macroeconomy. Moreover, Osei found that technological innovation and the complexity of agricultural exports primarily occur through a boost in human capital capabilities and the adoption of technologies in a region's local economy due to the build-up of digital infrastructure.

Synthesis and identification of literature gaps

Although the empirical literature provides significant insights into the effects of human capital and digital infrastructure separately on economic growth, there are important analytical gaps:

- Methodological Inconsistencies: Many cross-country panel studies use static estimators (Fixed Effects or Random Effects) or standard System GMM estimators, without appropriately addressing the possible non-stationarity, and long-run equilibrium processes across time series.
- Lack or exclusion of Joint Synergies: Empirical studies often measure human capital and digital infrastructure separately, without taking into account their interactive effects.
- Regional Heterogeneity: Multi-country panel often assume uniform slope parameters in heterogeneous economies (even though the slope parameters without recognizing country-specific structural features.

This study directly contributes to the literature by implementing a pure time-series ARDL modelling approach to Burkina Faso, for the joint analysis of digital infrastructure, human capital and physical capital while distinguishing long-run equilibrium relationship from short-run adjusted dynamics.

Methodology

Theoretical framework and model specification

This study is theoretically based on augmented endogenous growth theory and modern extensions of the neoclassical Solow-Swan growth theory. Standard neoclassical growth models assume that aggregate national output is a function of the amount of physical capital, the amount of labor input and the exogenous factor that captures total factor productivity (TFP) or technological progress. Endogenous growth models show, however, that economic production and long-term growth per capita are determined by non-rival, knowledge-based assets, structural efficiency gains and continuing capital accumulation. Information and Communication Technology (ICT) infrastructure is a general-purpose technology (GPT) in the modern digital economies. It reduces transaction costs, increases market efficiency, accelerates the diffusion of knowledge and increases the overall factor productivity of both the economy and all sectors. At the same time, investments in human health and physical infrastructure create institutional and productive capacity to effectively incorporate digital innovations.
The empirical specification in the log-linear form is given by:

$$\ln \mathrm{GDPPC}_t = \alpha_0 + \beta_1 \ln \mathrm{MCS}_t + \beta_2 \ln \mathrm{IUI}_t + \beta_3 \ln \mathrm{LEBT}_t + \beta_4 \ln \mathrm{GFCF}_t + \varepsilon_t$$

Where lnGDPPCt is the natural logarithm of Real GDP per capita, lnMCSt is the natural logarithm of Mobile Cellular Subscriptions, lnIUIt is the natural logarithm of Individuals Using the Internet, lnLEBTt is the natural logarithm of Life Expectancy at Birth, and lnGFCFt is the natural logarithm of Gross Fixed Capital Formation.

Bounds testing procedure for cointegration in a pure time-series setting

The bounds-testing method of Pesaran, Shin and Smith are suitable for the present investigation because it is a single-country time series for the period 1996 to 2024 that needs to be analyzed. The ARDL model estimation is presented in an unconstrained error-correction form, which is the starting point for the bounds test. Let lnGDPPCt be the natural log of real GDP per capita, lnMCSt be the natural log of the number of mobile cellular subscriptions per 100 people, lnIUIt be the natural log of the percentage of people using the Internet, lnLEBTt be the natural log of life expectancy at birth, and lnGFCFt be the natural log of gross fixed capital formation as a percentage of GDP. The unrestricted ARDL equation in first difference form is given by:

$$\begin{aligned}\Delta \ln GDPPC_t = \alpha_0 &+ \sum_{i=1}^{p} \alpha_i \Delta \ln GDPPC_{t-i} \\ &+ \sum_{j=0}^{q_1} \beta_j \Delta \ln MCS_{t-j} + \sum_{k=0}^{q_2} \gamma_k \Delta \ln IUI_{t-k} \\ &+ \sum_{m=0}^{q_3} \delta_m \Delta \ln LEBT_{t-m} + \sum_{n=0}^{q_4} \theta_n \Delta \ln GFCF_{t-n} \\ &+ \lambda_1 \ln GDPPC_{t-1} + \lambda_2 \ln MCS_{t-1} + \lambda_3 \ln IUI_{t-1} \\ &+ \lambda_4 \ln LEBT_{t-1} + \lambda_5 \ln GFCF_{t-1} + \varepsilon_t,\end{aligned}$$

Where Δ is the first-difference operator, p, q_1, q_2, q_3, q_4 are the respective lag orders, α0 is the intercept, and εt is assumed to be a white-noise process. The Akaike Information Criterion (AIC), and the maximum length chosen does not include too many degrees of freedom as the sample size is relatively small, about twenty-nine annual observations.
The bounds test only looks at the significance of the combination of the lagged level coefficients. The null hypothesis for the absence of long run levels relationship (no cointegration) is:

$$H_0: \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = 0,$$

while the alternative hypothesis asserts that at least one of the λ coefficients is different from zero. The asymptotic distribution of the Wald or F-statistic is non-standard under the null. Pesaran therefore supply two sets of asymptotic critical values: a lower-bound critical value that assumes all regressors are I (0) and an upper-bound critical value that assumes all regressors are I (1). If the computed F-statistic lies above the upper bound, the null of no cointegration is rejected irrespective of the true integration orders of the regressors. If the statistic is less than the lower number, the null is not rejected. We have a region that lies between the two bounds that we cannot determine the value of the function. Given the limited sample size in the present study, the finite-sample critical values tabulated by Narayan are also referenced to prevent inference from being skewed by the use of asymptotic critical values [19].

Once the existence of a level's relationship has been established, the long-run elasticities are recovered by normalizing the lagged level coefficients on the coefficient of the lagged dependent variable:

$$\beta^*_{MCS} = -\frac{\lambda_2}{\lambda_1}, \quad \beta^*_{IUI} = -\frac{\lambda_3}{\lambda_1}, \quad \beta^*_{LEBT} = -\frac{\lambda_4}{\lambda_1}, \quad \beta^*_{GFCF} = -\frac{\lambda_5}{\lambda_1}.$$

The normalized coefficients are the complete percentage change in real GDP per capita for a one percent change in each of the explanatory variables, assuming all short-run adjustments have taken place, while the other variables remain unchanged. Then the error-correction term is formed as a linear combination of the lagged levels

$$\begin{aligned} ECT_{t-1} = \ln GDPPC_{t-1} - \beta^*_{MCS} \ln MCS_{t-1} - \beta^*_{IUI} \ln IUI_{t-1} \\ - \beta^*_{LEBT} \ln LEBT_{t-1} - \beta^*_{GFCF} \ln GFCF_{t-1}. \end{aligned}$$

Substitution of this term into a restricted error-correction model yields the short-run dynamics:

$$\begin{aligned} \Delta \ln GDPPC_t = \sum_{i=1}^{p-1} \phi_i \Delta \ln GDPPC_{t-i} + \sum_{j=0}^{q_1-1} \psi_j \Delta \ln MCS_{t-j} \\ + \sum_{k=0}^{q_2-1} \omega_k \Delta \ln IUI_{t-k} + \sum_{m=0}^{q_3-1} \pi_m \Delta \ln LEBT_{t-m} \\ + \sum_{n=0}^{q_4-1} \rho_n \Delta \ln GFCF_{t-n} + \phi\, ECT_{t-1} + u_t. \end{aligned}$$

The coefficient ϕ on the lagged error-correction term represents the speed at which the deviations from the long-run equilibrium are corrected. For the equilibrium to be stable, ϕ must be negative and statistically significant; its absolute value indicates the fraction of any disequilibrium that is corrected within one year.

Selection of optimal lag length and model specification search

The selection of the length of the lag is a crucial intermediate step between the unit-root test and the bounds test. An under-parameterized model risks omitted-variable bias and residual serial correlation, while an over-parameterized model quickly has to use up the precious degrees of freedom and may yield vague estimates. In the present application, the maximum lag length is set to four, a typical value for annual data with sufficient number of observations after differencing and lagging. All possible ARDL specifications are estimated from this maximum and then ranked based on the Akaike Information Criterion. A more parsimonious alternative is calculated parallel to the Schwarz Bayesian Criterion. If the two criteria agree on the order of lag, that order is chosen; if they disagree, the one selected is based on residual diagnostics (especially lack of serial correlation) and statistical significance of the highest-order lag coefficients

Interpretation of the error-correction term

Furthermore, the value of ϕ can be directly interpreted economically. A minus sign of, say, –0.35 means that about 35 per cent of the gap from the long run growth path is closed in one year, making the half-life of a shock about two years. This kind of data has significant policy implications: it can suggest how fast the Burkinabè economy will recover to its equilibrium growth path following a short-term interruption in investment in the digital infrastructure, health consequences, or investment in physical infrastructure.

Residual diagnostics and model adequacy

The ARDL–ECM specification should pass a set of diagnostic tests of the residuals. The Breusch–Godfrey Lagrange-multiplier test is used to test for serial correlation, preferred to the Durbin–Watson statistic due to the latter being biased in the case of lagged dependent variables. Heteroskedasticity is examined with the ARCH test (which uses an autoregressive conditional heteroskedasticity test) and the White test (which is general test of heteroskedasticity that is robust to unknown forms of heteroskedasticity). The Jarque–Bera test is used to assess the residual normality; the null hypothesis of the Jarque–Bera test is that the residuals come from a normal distribution. The Ramsey RESET test is used to test for functional-form misspecification, by including powers of the fitted values in the original equation and testing the joint significance of them. Finally, influential observations or outliers are explored using leverage statistics and studentized residuals.

Robustness exercises and alternative specifications

A series of robustness checks are carried out within the ARDL–ECM framework. These include: (i) alternative lag structures around the preferred AIC specification, (ii) the addition of a linear deterministic trend, (iii) splitting the sample around 2010, (iv) the inclusion of dummy variables for possible structural breaks, and (v) the sequential exclusion of control variables. All the checks are kept within the single-equation ARDL–ECM approach with the AIC lag selection criterion.

Variable definitions, measurement, data sources and theoretical justification

Empirical analysis is based on all data available for Burkina Faso for the 1996-2024 period, all of which are annual observations. The starting year is determined by the first year to have consistently available digital-infrastructure indicators, and the ending year is that with the latest published indicators at the time of writing. The principal source is the World Bank's World Development Indicators (WDI) database, which offers internationally comparable series, based on standard methodologies (Table 1). The theoretical hypotheses for these explanatory variables are a-priori clear: all four variables are hypothesized to enter into the long-run equation with a positive sign. However, the size of the elasticities is up to an empirical question. Specifically, the relative size of the elasticities of the human-capital and physical-capital to the digital-infrastructure will characterize whether the growth process in Burkina Faso has already started to move toward knowledge- and connectivity-based sources of productivity improvement.

Table 1: *Variable Measurement and Operational Definitions.*

Variable Code	Structural Function	Indicator Name	Unit of Measurement	Source Database	A Priori Expectation
GDPPC_t	Real GDP per Capita	Dependent Variable	Constant USD (2015 = 100)	World Development Indicators (WDI)	NA
MCS_t	Explanatory Variable	Mobile Cellular Subscriptions	Subscriptions per 100 people	World Development Indicators (WDI)	Positive ($\beta_1 > 0$)
IUI_t	Explanatory Variable	Individuals Using the Internet	Percentage (%) of population	World Development Indicators (WDI)	Positive ($\beta_2 > 0$)
LEBT_t	Control Variable	Life Expectancy at Birth	Total years at birth	World Development Indicators (WDI)	Positive ($\beta_3 > 0$)
GFCF_t	Control Variable	Gross Fixed Capital Formation	Percentage (%) of GDP	World Development Indicators (WDI)	Positive ($\beta_4 > 0$)

Econometric strategy: sequence of estimation and inference

The empirical strategy unfolds in a carefully ordered sequence designed to ensure that each subsequent step rests on a statistically secure foundation. The first stage consists of a thorough examination of the time-series properties of the five logarithmic variables. Augmented Dickey–Fuller, Phillips–Perron, and KPSS tests are applied both to the levels and to the first differences, with lag lengths selected by the AIC and with alternative assumptions concerning the deterministic components (intercept only, intercept and trend). The objective is to establish that every series is I(1) and that none is I(2). The second stage is the selection of the optimal lag structure for the unrestricted ARDL model, as described in section 3.3. The third stage is the formal bounds test for the existence of a long-run levels relationship. Only if cointegration is confirmed does the analysis proceed to the fourth stage—the recovery of the long-run elasticities and the estimation of the restricted error-correction model. The fifth stage comprises the full suite of residual diagnostics and parameter-stability tests. The sixth and final stage consists of the robustness exercises outlined in section 3.8.

Empirical Results and Discussion

Results and discussion

This chapter presents empirical results of the ARDL–ECM applied to annual time-series data for Burkina Faso ranging 1996 to 2024. The results are organized according to the sequential estimation strategy outlined in Chapter 3. The discussion starts with descriptive evidence, proceeds through unit-root testing and lag selection, the determination of the existence of a long-run cointegrating relationship, and the reporting of the long run elasticities, short-run dynamics, residual diagnostics and parameter-stability tests. Throughout, the interpretation of the coefficients is always tied to the theoretical structure outlined above and to the economy's particular structural features of the Burkinabè economy.

Descriptive statistics

Purpose of the analysis

The descriptive statistics are used to give a preliminary description of the central tendency, dispersion, range and distributional shape of the five variables used in the study. This step is crucial prior to formal unit-root testing and ARDL estimation because it provides insight into the characteristics of the data, identifies the data's potential non-linearities, its outliers, and aids in subsequent logarithmic transformation and model specification.

Presentation of Results

The mean, median, maximum, minimum, standard deviation, skewness and kurtosis for real GDP per capita, individuals using the Internet, life expectancy at birth, mobile cellular subscriptions and gross fixed capital formation for 1996 through 2024 (Table 2).

Table 2: *Descriptive Statistics.*

Statistics	GDPPC	Internet IUI	Life expectancy (LEBT)	Moblie (MCS)	GFCF
Mean	570.5292	6.025859	55.81403	46.44557	18.61317
Median	561.8472	2.400000	56.34300	35.28483	18.36619
Maximum	764.0826	28.25270	61.29200	116.5896	24.22602
Minimum	383.9736	0.000961	49.56000	0.004943	13.35961
Std. Dev.	119.9540	8.318096	3.999047	44.80754	2.832645
Skewness	0.110689	1.579469	-0.185394	0.323097	0.081912
Kurtosis	1.708479	4.355431	1.559350	1.492384	2.402232
The results of the statistics are explained.					

Table 3: *Unit-Root Tests.*

Variable	Level ADF Statistic	Level p-value	First Difference ADF Statistic	First Difference p-value	Order of Integration	Decision
GDPPC	0.006663	0.9515	-6.828311	0.0000	I(1)	Stationary at first difference
LEBT	-0.922837	0.7657	-4.939280	0.0005	I(1)	Stationary at first difference
IUI	3.716859	1.0000	-4.786302	0.0040	I(1)	Stationary at first difference
GFCF	-1.998007	0.2859	-4.568872	0.0012	I(1)	Stationary at first difference
Interpretation of the Statistical Results:						

The results of the statistics are explained

The mean of real GDP per capita is 570.5 USD and the median is 561.8 USD with a moderate standard deviation of 120.0 USD and nearly zero skewness of 0.11. Mean of Internet usage is low (6.03 per cent), and median is much lower (2.40 per cent), with high positive skewness (1.58) and high kurtosis (4.36). Life expectancy has a mean value of 55.81 years, a low range (49.56–61.29) and the lowest standard deviation (4.00). The mean of mobile subscriptions is 46.45 with a high standard deviation of 44.81 and slight positive skewness of 0.32. Gross fixed capital formation has the least volatile series with the smallest standard deviation of 2.83 and the smallest skewness (0.08) and is almost symmetrically distributed.

Unit-Root Tests

The unit-root tests aim at establishing the order of integration of each time series prior to estimating the ARDL model.

Presentation of Results

The ADF test statistics and the associated p-values for the variables in levels and first differences are reported in Table 2, and the inferred order of integration is reported in the (Table 3).

Interpretation of the Statistical Results

At levels, the ADF statistics for all four variables are statistically insignificant (p-values = 0.2859–1.0000), indicating failure to reject the null hypothesis of a unit root. After first differencing, all variables become statistically significant (p-values = 0.0000–0.0040), indicating stationarity. Hence, there are no variables of order two, I(2), and all variables are integrated of order one, I(1). These results provide the statistical basis for applying the ARDL bounds test approach.

ARDL bounds test for cointegration

The purpose of the ARDL bounds test is to determine whether a statistically significant long-run (levels) relationship exists among real GDP per capita, mobile cellular subscriptions, internet usage, life expectancy at birth and gross fixed capital formation.

Presentation of Results

Table 3 reports the computed F-statistic from the bounds test together with the critical value bounds at the 10 percent, 5 percent and 1 percent significance levels (Table 4). The computed statistic F is 6.2422, which is greater than the critical value I(1) at any conventional significance level, including the most severe 1 percent level (5.840). Thus, the null hypothesis is rejected as the result is very unlikely to be due to chance. The result corroborates the existence of a unique cointegrating vector among the five variables for the time period 1996 to 2024. The bounds test provides statistical support for the study's central hypotheses by validating a stable long run equilibrium between digital infrastructure, human capital, physical capital and real GDP per capita.

Table 4: *Bounds Test for Cointegration.*

Test Statistic	Computed Value	Significance Level	I(0) Bound	I(1) Bound	Hypothesis Decision
F-statistic	6.2422	10%	2.525	3.560	Reject H_0
		5%	3.058	4.223	Reject H_0 ($p < 0.05$)
		1%	4.280	5.840	Reject H_0 ($p < 0.01$)
Interpretation of the Statistical Result:					

Table 5: *Long-Run Coefficients (Levels Equation).*

Variable	Description	Conditional Coeff.	Long-Run Elasticity (θk)	Std. Error	t-Statistic	p-Value	Decision (p<0.05)
LEBT	Life Expectancy at Birth	12.0517	+23.8132	4.5500	2.6487	0.0150	Statistically Significant
IUI	Individuals Using Internet	0.7070	+1.3970	0.6740	1.0490	0.3061	Not Significant
MCS	Mobile Cellular Subscriptions	0.1592	+0.3146	0.3138	0.5073	0.6173	Not Significant
GCFC	Gross Fixed Capital Formation	−0.7054	−1.3938	0.9004	−0.7834	0.4422	Not Significant
C	Constant	−367.5672	−726.2842	163.4986	−2.2481	0.0354	Statistically Significant
Interpretation of the Statistical Results							

Long-run coefficients

The purpose of estimating the long-run coefficients is to quantify the equilibrium elasticities of real GDP per capita with respect to life expectancy, internet usage, mobile cellular subscriptions and gross fixed capital formation once cointegration has been established. These elasticities represent the percentage change in real GDP per capita resulting from a one percent change in each of the explanatory variables, holding the others constant.

Presentation of Results

Table 4 reports the long-run elasticities derived from the ARDL levels relationship, together with their standard errors, t-statistics, p-values and statistical decisions (Table 5). Only life expectancy at birth (LEBT) and the constant term are statistically significant at the 5% level in the long-run equation. Internet use (IUI), mobile cellular subscriptions (MCS) and gross fixed capital formation (GFCF) are not statistically significant. This suggests that health capital contributes significantly to the dynamics of real GDP per capita in Burkina Faso over the long run, while digital infrastructure and physical capital do not have a statistically significant long-run relationship in the estimated model.

Table 6: *Error-Correction Model and Short-Run Dynamics.*

Variable	Description	Coefficient	Std. Error	t-Statistic	p-Value	Interpretation
COINTEQ* (EC_{t-1})	Error Correction Term	−0.5061	0.0743	−6.8096	0.0000	Speed of adjustment (**50.61% per year**)
D(LEBT)	Short-Run LEBT	−7.1257	5.3168	−1.3402	0.1918	Short-run effect (Not Significant)
Interpretation of the Statistical Results						

Table 7: *Diagnostic Tests and Parameter Stability.*

Category	Metric / Test	Null Hypothesis (H0)	Value / Statistic	Result / p-Value	Decision / Conclusion
Goodness of Fit	R-squared (R^2)	—	0.3651	36.51%	Explanatory power for short-run dynamics
	Adjusted R^2	—	0.3407	34.07%	Fits sample size and lag structure
	Durbin-Watson statistic	—	2.0959	≈ 2.00	No first-order autocorrelation
Residual Diagnostics	Breusch-Godfrey Serial Correlation LM	Residuals are not serially correlated	$Obs \cdot R^2 = 3.1775$	$p = 0.2042$	Passed: Fail to reject H_0 ($p > 0.05$)
	Breusch-Pagan-Godfrey Heteroskedasticity	Residuals are homoskedastic	$Obs \cdot R^2 = 4.0131$	$p = 0.6749$	Passed: Fail to reject H_0 ($p > 0.05$)
Stability Diagnostics	CUSUM Test	Coefficients are stable	Blue line within bounds	5% Significance level	Passed: Structural parameter stability
	CUSUM of Squares Test	Error variance is stable	Converges within bounds	Mid-sample shift	Passed: Structural variance stability

Economic Meaning

The important positive impact of life expectancy reinforces the health-capital framework of Grossman and the macroeconomic theories of Bloom and Canning.

Support for the Study's Hypotheses

The long-run results partially support the study's hypotheses. The hypothesis that human capital (life expectancy) has a positive impact on economic growth is supported, while the hypothesis regarding long run impacts of digital infrastructure and physical capital formation are not statistically supported for this specification

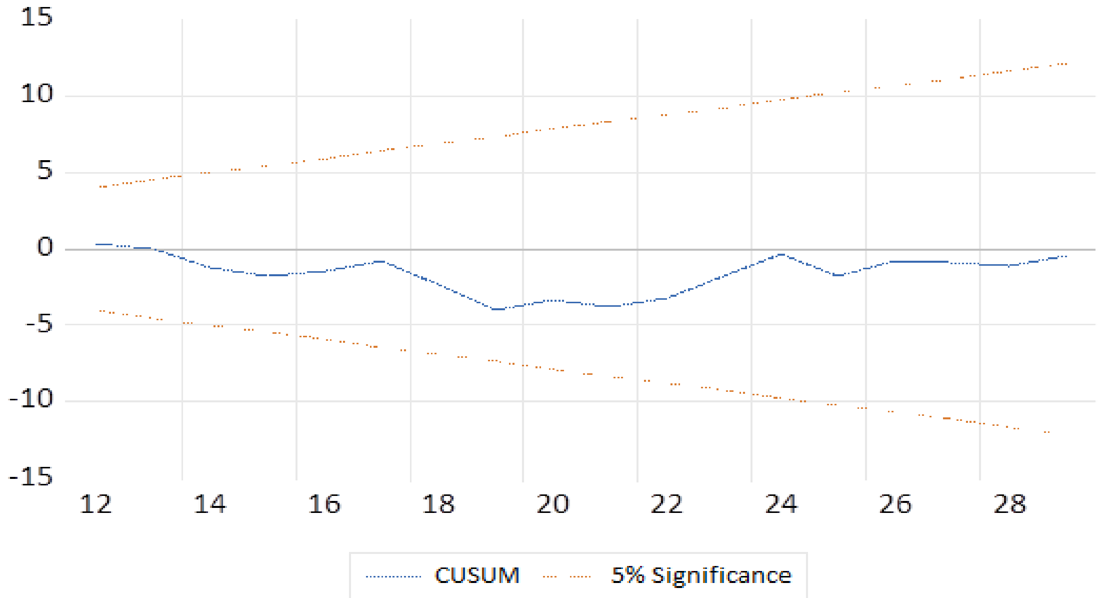
Short-run dynamics & error correction model (ECM)

The purpose of estimating the error-correction model is to examine the short-run dynamics of real GDP per capita and to measure the speed at which the Burkinabè economy adjusts back to its long-run equilibrium after a shock (Table 6). The negative coefficient of the lagged error-correction term suggests that the error-correction effect takes about half a year to complete, and around 50.61 percent of any error from the long-run equilibrium is corrected within one year. This is a rather quick speed of adjustment. The short-run coefficient on life expectancy is statistically insignificant, meaning that its effect on real GDP per capita is not detectable in the same year as it changes, once the long-run relationship is considered. The significant error-correction term confirms the existence of a stable long-run equilibrium, while the insignificant short-run effect of life expectancy suggests that the influence of health capital operates primarily through long-run channels.

Summary of model and residual diagnostic checks

The residual diagnostic and parameter stability tests aim at confirming that the estimated ARDL error correction model is statistically acceptable and that the model's parameters are stable for the sample period. Satisfactory diagnostics of residuals ensure validity of standard inference, and the CUSUM and CUSUM of Squares tests ensure that the long run and short run parameters are stable and free from possible structural breaks that could affect the results (Table 7).

All of the standard diagnostic tests are fulfilled at the conventional significance level in the model. There is no serial correlation as indicated by the Breusch–Godfrey LM test and no heteroskedasticity as shown by the Breusch–Pagan–Godfrey test. There is no first order autocorrelation as well, indicated by the Durbin-Watson statistic. The CUSUM and the CUSUMS of the square’s plots are both within the 5% critical bands, and the parameters are stable across the sample, although there is a minor small change in the residual variance in the middle of the sample that is not statistically significant (Figure 1).



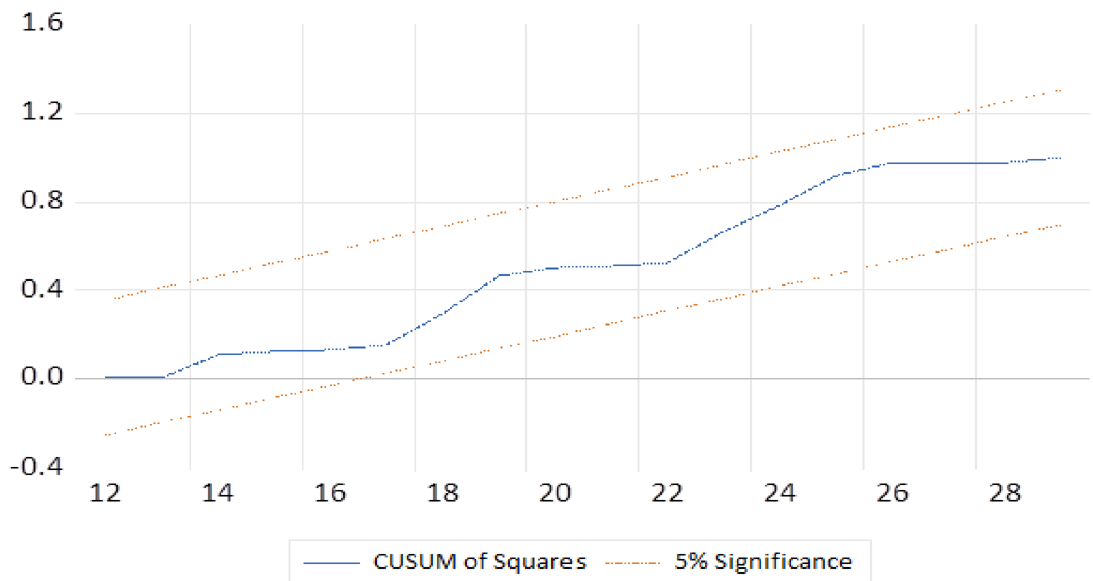


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Figure 1: *Interpretation of the Statistical Results.*

The satisfactory residual diagnostics and parameter stability increases the trustworthiness of the empirical results. The long run persistence of life expectancy and the relatively fast error correction are considered to be strong, due to the absence of serial correlation and heteroskedasticity in the model, and stable coefficients. The results confirm the main hypothesis of the study about the long-run relationship between human capital (health) and economic growth in Burkina Faso

Conclusion and Policy Recommendations

Summary of key findings

This study examined the effects of digital infrastructure and human capital development on economic growth in Burkina Faso over the period 1996–2024 using the ARDL bounds-testing approach. The empirical results show that all variables are integrated of order one, I(1), and that a long-run cointegrating relationship exists at the 1% significance level. Among the explanatory variables, only life expectancy at birth, as a proxy for human capital, is statistically significant in the long run, whereas internet usage, mobile cellular subscriptions, and gross fixed capital formation are not. The error-correction term is negative and statistically significant, indicating that approximately 50.61% of short-run disequilibrium is corrected within one year, implying a relatively rapid adjustment toward the long-run equilibrium. Diagnostic tests show no evidence of serial correlation or heteroskedasticity, and CUSUM and CUSUM of Squares tests suggest that the parameters do not change over the sample period. Overall, the results indicate that human capital, measured in life expectancy at birth, has the most significant long-run effect on economic growth in Burkina Faso, as measured by the variables considered, while the effects of digital infrastructure and physical capital formation are not statistically significant in the preferred specification. The results suggest that the impact on health outcomes is more closely linked to economic growth in the long-term than simply to the digital infrastructure, emphasizing the need for complementary investments in human capital to extract the growth potential of digital development.

Theoretical and empirical contributions

This study makes three important contributions to the literature. First, it provides one of the few single-country time-series analyses examining the joint effects of digital infrastructure and human capital on economic growth in a Sahelian economy. Unlike most existing studies, which rely on multi-country panel data and assume slope homogeneity, this study captures country-specific dynamics in Burkina Faso. Second, it implies the ARDL bounds-testing approach, incorporating appropriate lag selection, residual diagnostics and parameter stability tests, thereby addressing common methodological challenges associated with time-series data developing economies. Third, the findings qualify the widely held view that digital infrastructure independently promotes long-run economic growth. While human capital, measured by life expectancy, exerts a significant long-run effect, internet usage, mobile cellular subscriptions and physical capital formation do not exhibit statistically significant independent long-run effect in the preferred specification for Burkina Faso between 1996 and 2024 [20-36].

Recommendations

Based on the empirical findings, the following recommendations are proposed:

Increase long-term investment in health capital.

Given that only life expectancy has a significant long-run impact on real GDP per capita, the government needs to focus on programmers' that enhance the health of the population, such as an expansion of primary healthcare, a decrease in infant and maternal mortality rates, nutrition and vaccination.

Create complementary conditions for Digital Infrastructure

Although mobile subscriptions and internet usage are not individually significant in the long run, their expansion remains important. Digital investments should be supported by improved electricity access, digital skills training, affordable data, and a conducive regulatory environment.

Increase quality and efficiency of physical capital investment

Priority should be placed on enhancing the quality, efficiency and productivity of public and private investments, especially in human capital and digital transformation.

Follow an integrated growth approach.

There is a need for coordinated policies that will advance health outcomes, productive investment and meaningful digital access.

Suggestions for Future Research

Future research could incorporate education-based measures of human capital (such as secondary or tertiary enrolment rates), test interaction terms between digital infrastructure and life expectancy, and explore threshold or non-linear ARDL models. Extending the time series with more recent data or conducting comparative analyses with other Sahelian countries would further strengthen the evidence base.

Concluding Remarks

This study finds a stable long-run relationship between digital infrastructure, human capital, physical capital and economic growth in Burkina Faso. The independent contribution of digital infrastructure is small in the current specification, and life expectancy consistently drives real GDP per capita in the long run. The relatively rapid speed of adjustment indicates that the economy reacts systematically to deviation from equilibrium. These findings underscore the central importance of health-capital accumulation for long-run growth and the need for complementary policies to enhance the effectiveness of digital and physical investments.

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