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DIGITAL TECHNOLOGY AND THE ECONOMIC GROWTH: AN EMPIRICAL EVIDENCE FROM SOUTH ASIA

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ABSTRACT

Objective: This paper examines how digital technologies–specifically internet and mobile-phone penetration–drive economic growth in six South Asian economies over the period 1990–2021. Although broadband access and mobile connectivity have rapidly expanded across the region, the literature lacks a systematic assessment of their long-run growth effects.

Methodology/Design: We address this gap by assembling a balanced panel of annual data for Bangladesh, India, Pakistan, Sri Lanka, Bhutan and Nepal, and applying panel-cointegration techniques alongside Dynamic OLS (DOLS) and Fully Modified OLS (FMOLS) estimators. Pedroni, Kao, and Westerlund tests all confirm a stable long-run relationship among GDP per capita, internet usage, mobile-phone subscriptions, and key control variables.

Findings: Our results reveal bidirectional Granger causality between digital technology adoption and economic growth, and robustly positive long-run elasticities: a 1 percent increase in internet users raises per-capita GDP by approximately 0.15 percent, while a similar rise in mobile subscriptions boosts GDP by around 0.10 percent. These findings underscore the crucial role of affordable, high-quality digital infrastructure in enhancing productivity, fostering entrepreneurship, and improving household welfare.

Policy recommendation: We recommend that South Asian policymakers deepen regional cooperation on broadband expansion, invest in rural connectivity, and adopt regulatory reforms to lower service costs–measures that will help translate digital diffusion into sustained, inclusive economic development.

Keywords: *Internet; Mobile; South Asia; Welfare, Technology*
JEL classification: A11, B17, D6, L96, M15

INTRODUCTION

Over the last two decades, South Asia has experienced a profound digital transformation, driven by the rapid diffusion of high-speed broadband, widespread internet access, and ubiquitous mobile-phone usage. Dubbed the "digital dividend," this revolution promises to lower transaction costs, expand market reach, and spur innovation—from e-commerce startups bootstrapped on smartphones to online platforms delivering financial services in rural areas (Verhoef et al., 2021; Broadbent & Papadopoulos, 2013). Recognizing the pivotal role of connectivity, the United Nations' Broadband Commission (2011) urged governments to invest in universal high-speed internet to achieve the Sustainable Development Goals, and South Asian policymakers have since launched national broadband plans and public–private

partnerships to extend coverage (Yiu & Fink, 2012; Picot & Wernick, 2007). Yet, alongside these gains, concerns over cybercrime and online fraud highlight potential risks that may offset digital benefits (Acemoglu et al., 2014; Galperin et al., 2017).

Despite this policy focus and the wealth of anecdotal evidence, rigorous empirical studies quantifying how internet and mobile adoption translate into macroeconomic gains remain scarce for South Asia. Most research on ICT-driven growth has concentrated on advanced economies, leaving a critical gap in our understanding of digital technology's contribution to economic expansion in developing contexts. In particular, the extent to which internet penetration and mobile subscriptions foster GDP growth—and whether these effects operate in both directions—has not been systematically examined for Bangladesh, India, Pakistan, Nepal, Sri Lanka, and Bhutan. This study addresses that gap by assembling a quarter-century panel (1990–2021) and applying Pedroni, Kao, and Westerlund cointegration tests alongside DOLS and FMOLS estimators to capture both long-run elasticities and short-run dynamics.

Our analysis yields three key contributions. First, we establish a bidirectional causal nexus between digital technology use and per-capita GDP, demonstrating that a 1 percent increase in internet users raises GDP by approximately 0.15 percent, while mobile-phone penetration delivers a 0.10 percent boost. Second, we show that these growth effects are robust to concerns over cyber-risks and financial-market distortions. Finally, we derive actionable policy insights: by deepening regional cooperation on broadband infrastructure, reducing service costs, and strengthening cybersecurity frameworks, South Asian governments can more effectively harness the digital dividend for inclusive, sustained economic growth. In doing so, this paper fills a critical void in the literature and provides a roadmap for leveraging digital technologies to advance development objectives across the region..

1.1 Internet and economic growth in the Region of South Asia at a Glance

Over the past decade and a half, South Asia has undergone a remarkable digital transformation, with internet penetration soaring from under 10 percent in 2005 to nearly 35 percent by 2020 (Figure 1). Countries such as Bhutan and Sri Lanka led the region—Bhutan now boasts the highest connectivity rate—thanks to sustained investments in broadband infrastructure and mobile-network expansion (World Bank, 2022). This rapid diffusion of internet access, coupled with the spread of 4G mobile services, has narrowed—but not eliminated—the digital divide, which remains pronounced along income, educational, and urban–rural lines. At the

same time, economic performance has strengthened: per-capita GDP in Sri Lanka and Bhutan has more than doubled since 2005, while Bangladesh, India, Pakistan, and Nepal have all seen steady gains (Figure 3). The contemporaneous rise in digital connectivity and living standards suggests a powerful linkage, as businesses leverage e-commerce, remote work, and digital financial services to drive productivity and inclusivity (Guillén & Suárez, 2005; Verhoef et al., 2021).

Despite these encouraging trends, rigorous research on how digital technology translates into macroeconomic growth remains scarce for South Asia. Existing studies tend to focus on advanced economies or examine isolated case studies within the region, leaving a gap in our understanding of the long-run, reciprocal relationship between internet/mobile adoption and economic expansion. This paper fills that gap by assembling an annual panel for six South Asian countries (Bangladesh, Bhutan, India, Nepal, Pakistan, and Sri Lanka) over 1990–2021.

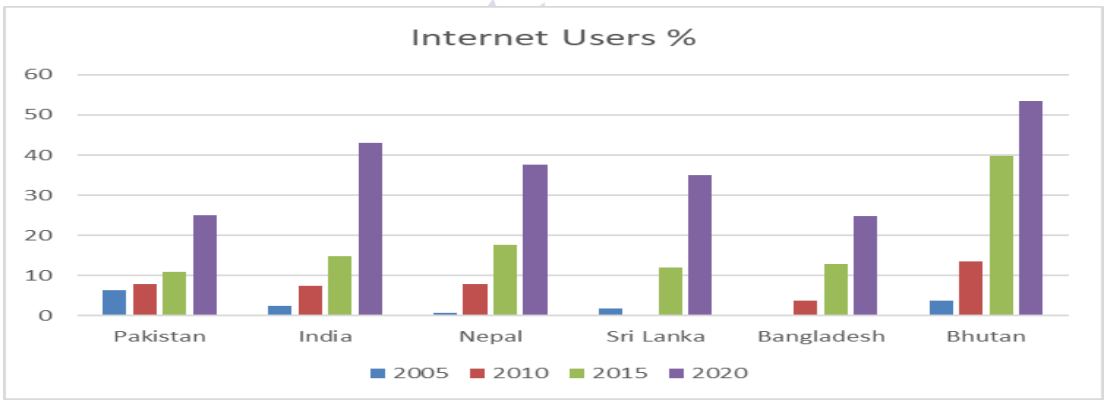


Figure 1 Internet Users

We first document the evolution of digital-connectivity indicators and GDP per capita (Figures 1–3), then apply panel-unit-root tests and Pedroni, Kao, and Westerlund cointegration tests to confirm long-run co-movement. Dynamic OLS (DOLS), Fully Modified OLS (FMOLS), and Granger-causality analyses unpack both the elasticities and the direction of causation between digital-technology use and economic growth

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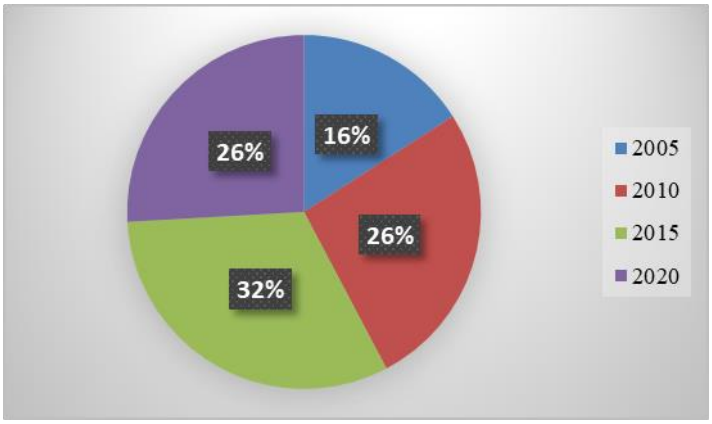


Figure 2. Internet users during 2015-2020 in the South Asia (Author)

In South Asia, this divide is often influenced by income, education, and geography, and addressing it is crucial for ensuring equitable economic development. This issue needs urgent attention to ensure fair and balanced economic growth in the region.

The continuous increase in GDP per capita in South Asian countries is a testament to the region's economic growth. Effective economic policies and supportive conditions have significantly improved economic growth from 2005 to 2020, as shown in Figure 3.

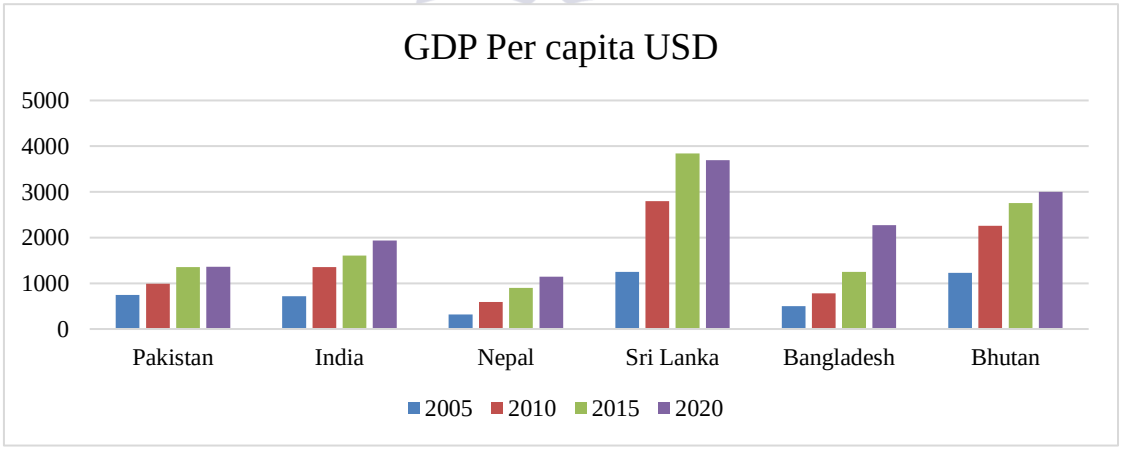


Figure 3. GDP per capita South Asian countries; Source: Author's self-creation

Figure 3 shows the GDP per capita of South Asian countries, with Sri Lanka and Bhutan having the highest in 2020. Bangladesh, India, Pakistan, and Nepal followed closely, with GDP of 2270.34, 1933.10, 1359.51, and 1147.47 in 2020. These countries experienced continuous GDP per capita increases, indicating gradual performance improvement. The study reveals a significant correlation between internet use and

economic growth in South Asia from 2005 to 2020. The increase in internet usage and GDP per capita in these countries doubled between 2005 and 2015, with Bhutan leading the way. The positive trends in internet use and GDP per capita suggest that internet use, with its potential to enable people to lead prosperous lives, has become a powerful tool for economic development (Guillen & Suarez, 2005). This underscores the Internet's crucial role in economic growth in South Asia and inspires us with its transformative potential, instilling a sense of hope about the future of economic growth in the region.

The remainder of this study is structured as follows. Section 2 reviews the literature on digital dividends, highlighting how internet and mobile penetration foster innovation, reduce transaction costs, and enhance welfare. Section 3 describes our data sources, variable construction, and estimation techniques. Section 4 presents the econometric results, demonstrating a robust, bidirectional nexus between digital-technology adoption and GDP per capita. Finally, Section 5 concludes with policy implications—calling for targeted investments in affordable connectivity, regulatory reforms to lower digital-service costs, and cross-border partnerships to bridge the digital divide—and offers avenues for future research on cybersecurity, digital skills, and subnational disparities in South Asia.

Literature Review

Over the past two decades, scholars have increasingly recognized high-speed internet as a catalyst for economic development, reducing traditional transaction costs and enabling new business models (Bloom et al., 2009; Czernich et al., 2011). Early foundational work draws on Coase's (1937) transaction-cost framework to show how information-sharing expenses fall dramatically when market participants adopt digital platforms, transforming once-cumbersome processes—such as bank transfers and payment settlements—into near-instantaneous, click-based interactions (World Bank, 2016). Rifkin (2014) further argues that, by lowering marginal transaction costs to near zero, online businesses can emerge and scale with minimal upfront capital, a phenomenon borne out by the rapid proliferation of e-commerce ventures across Asia (Carter, 2010; Vinaja, 2013; Tuncalp, 2014).

Building on these theoretical insights, a body of empirical research has documented the positive links between Information and Communication Technologies (ICTs) and macroeconomic performance. Asongu and Le Roux (2017) and Asongu et al. (2018) use panel regressions to show that stronger broadband and mobile penetration spur GDP growth through enhanced productivity and

innovation. Vu (2011) applies country-fixed and mechanism-controlled models to 1996–2005 data, finding that ICT adoption raises output levels despite heterogeneity in institutional environments. These findings are reinforced by Das et al. (2018), Latif et al. (2018), and Harindranath (2008), who emphasize that ICT investments lower production costs, improve decision-making, and facilitate economies of scale, while Turel et al. (2006) highlight sector-specific gains such as advanced supply-chain coordination. Yet, the empirical literature also exposes important caveats and context-dependence. Galperin and Viecens (2017) caution that without complementary investments in human capital and regulatory reform, the digital dividend may accrue disproportionately to high-income groups, thereby exacerbating inequality. Indeed, Ahmad et al. (2022) demonstrate that, in South Asia, greater ICT use can widen the income gap absent targeted inclusion policies. Similarly, Murshed et al. (2020) document that liberalizing ICT trade barriers—while boosting digital connectivity—can intensify environmental pressures, raising CO_2 emissions in the absence of clean-energy safeguards.

In the health and social sectors, the nexus between ICTs and welfare gains remains underexplored in developing contexts. Adeola and Evans (2018) find bidirectional causality between ICT use and health outcomes, suggesting that improved digital access enhances service delivery and human development. Naz et al. (2020) show that affordable mobile internet empowers students to pursue online education, leading to higher-paid employment opportunities. However, evidence from rural Bangladesh (Rahman et al., 2013; Meah, 2012) indicates persistent digital divides—driven by income, education, and geography—that limit the reach of digital-health and e-financial services.

Although these studies collectively underscore the transformative potential of digital technologies, South Asia remains relatively under-researched compared to advanced economies. Only a handful of studies—Sunita et al. (2019), Rahman et al. (2013), and Meah (2012)—investigate ICT impacts within the region, often using qualitative or short-span panel designs. Moreover, the dynamic interplay between internet/mobile penetration and macro-level growth has yet to be examined using state-of-the-art panel-cointegration and causality techniques.

Synthesis and Research Gap

In sum, while the literature establishes that ICTs can lower transaction costs, spur productivity, and improve economic growth, it also highlights conditionalities: gains depend on complementary human-capital investments, inclusive policies, and

environmental safeguards. Crucially, South Asian countries—characterized by rapid digital expansion but stark regional disparities—require a systematic, long-run analysis of how internet and mobile adoption translate into GDP growth, and vice versa. Our study addresses this gap by employing Pedroni, Kao, and Westerlund cointegration tests alongside DOLS, FMOLS, and Granger-causality methods on a 1990–2021 panel of six South Asian economies, thereby offering the first comprehensive assessment of the digital-technology–growth nexus in this pivotal region.

3. Methodology

3.1 Econometric Model

To examine the impact of digital technologies on economic growth in South Asia, we specify a log-linear panel regression adapted from Evans (2019). Our baseline model relates real per-capita GDP (ECWit) to key digital-technology indicators—internet penetration (Intit) and mobile subscriptions (Mphit)—while controlling for institutional quality, investment, human capital, and trade openness. All variables are expressed in natural logarithms to interpret coefficients as elasticities and to stabilize variance. The estimating equation is:

$$lnECW_{it} = \mathrm{k}_0 + k_1\ lnInt_{it} + k_2\ lnMph_{it} + \mathrm{k}_3 lnCfm_{it} + \mathrm{k}_4 lnCor_{it} + \mathrm{k}_5 lnEdu_{it} + \mathrm{k}_6 lnTrd_{it} + \epsilon_{it} \quad (1)$$

In Equation (1), i denotes the number of South Asian countries selected for the present research, t represents the time frame, and k signifies the coefficients of the independent variables. In contrast, The dependent variable, ln(ECWit)), is the logarithm of real GDP per capita, our proxy for economic growth. Our primary regressors are ln(Intit), the share of individuals using the internet, and ln(Mphit), mobile-cellular subscriptions per 100 inhabitants—both central facets of digital technology diffusion. We control for ln(Corit), the corruption perception index (a higher value denotes lower corruption), recognizing that institutional quality mediates technology's growth payoffs. Investment dynamics enter via ln(Cfmit), gross capital formation as a share of GDP, while human-capital accumulation is proxied by ln(Eduit), primary-school enrollment rates. Finally, ln(Trdit) captures trade openness (exports plus imports as a percentage of GDP), given its well-documented complementarity with ICT adoption.

3.2 Sampling and Data Sources

This study employs an unbalanced panel of six South Asian countries—Bangladesh,

Bhutan, India, Nepal, Pakistan, and Sri Lanka—over the period 1990–2021. Annual data for all variables were sourced from the World Bank's World Development Indicators (WDI) database. These six countries were selected because consistent time-series observations on key digital-technology and control variables are available for the full sample period. Data for Afghanistan and the Maldives, by contrast, are either missing or intermittently reported, and were therefore excluded to preserve the robustness and comparability of our empirical analysis. All series are denominated in levels or percentages, then transformed via natural logarithms before estimation to interpret coefficients as elasticities and to mitigate heteroskedasticity. A detailed variable list and data coverage by country are provided in table-1

Table 1. Variables Description and source of data.

Acronym	Variables	Unit	Sources
ECW	Real economic growth	Growth rate of real of GDP	WDI-2022
Int	Internet users	% of total population	WDI-2022
Mph	mobile subscriptions	% of the population	WDI-2022
Cor	corruption	rating 1-6	WDI-2022
Cfm	capital formation	% of GDP	WDI-2022
Edu	primary school enrolment	rating 1-6	WDI-2022
Trd	trade openness	% of GDP	WDI-2022

3.3 Estimation Techniques

We begin our empirical analysis by assessing the stationarity properties of each series using a battery of panel-unit-root tests, including Breitung (2000), Im, Pesaran, and Shin (2003), and the ADF-Fisher chi-square test of Maddala and Wu (1999). These complementary approaches allow us to

distinguish between country-specific and common unit-root processes and offer greater power and less restrictive assumptions than earlier methods (Evans, 2019). Having established the integration order of our variables, we test for a long-run equilibrium relationship using the Kao (1999) panel-cointegration test, which accommodates heterogeneous intercepts across cross-sections while imposing homogeneous slope coefficients. Although the Kao framework assumes a common cointegrating vector—an assumption highlighted by Lean and Smyth (2010) and Evans (2019)—its parsimony makes it well suited for our six-country sample. Where cointegration is confirmed, we estimate long-run elasticities via Fully Modified OLS (FMOLS) and Dynamic OLS (DOLS), both of which correct for endogeneity and serial correlation in the cointegrating regressions.

3.4.Panel Long-run Estimates

After confirming that our series are integrated and share a cointegrating relationship, we estimate the long-run elasticities using two complementary panel-cointegration techniques: Dynamic Ordinary Least Squares (DOLS) and Fully Modified Ordinary Least Squares (FMOLS) (Stock & Watson, 1993; Phillips & Hansen, 1990).

Panel DOLS. Ordinary least squares (OLS) applied to cointegrated panels can yield biased and inconsistent estimates due to endogeneity and serial correlation. Pedroni (2001) extends the DOLS framework to panel data by augmenting the cointegrating regression with country-specific leads and lags of first-differences of all regressors. This "parametric correction" effectively purges the residuals of feedback effects and autocorrelation, delivering unbiased and super-consistent estimates of the long-run coefficients even in the presence of endogenous regressors (Osuntuyi & Lean, 2023).

Panel FMOLS. In contrast, FMOLS employs a "nonparametric correction" to adjust the OLS estimator for both endogeneity and serial correlation. It computes a semi-parametric adjustment to the residuals of the pooled cointegrating regression, allowing for heterogeneous variances and covariances across cross-sections (Pedroni, 2000). The result is an estimator that retains the full levels information—avoiding the loss of long-run variation inherent in differencing—while accounting for dynamic feedback among the variables.

By applying both DOLS and FMOLS to our six-country panel, we exploit their respective strengths: DOLS' explicit lag-lead structure controls for dynamic endogeneity, and FMOLS' residual adjustment delivers robust long-run parameter estimates. In this way, we quantify the elasticities of economic growth with respect to Internet penetration, mobile-subscription rates, gross capital formation,

primary-school enrollment, and trade openness without sacrificing long-run information or biasing our results through uncorrected dynamic feedback. The Stock-Watson DOLS model, after taking the natural log used in the present study, is specified (Ehigiamusoe & Lean, 2019) as follows:

$$\begin{aligned} lnECW_{it} = {} & k_0 + k_1\ lnInt_{it} + k_2\ lnMph_{it} \\ & + k_3 lnCfm_{it} + k_4 lnCor_{it} \\ & + k_5 lnEdu_{it} + k_6 lnTrd_{it} \\ & + \sum_{i=-l}^{i=l} \alpha_i\, \Delta lnMph_{it} \\ & + \sum_{i=-m}^{i=m} \beta_i\, \Delta lnCfm_{it} \\ & + \sum_{i=-n}^{i=n} \gamma_i\, \Delta lnCor_{it} \\ & + \sum_{i=-o}^{i=o} \theta_i\, \Delta lnEdu_{it} \\ & + \sum_{i=-p}^{i=p} \mu_i\, \Delta lnTrd_{it} + \\ & \in_{it} \qquad (2) \end{aligned}$$

In Equation 2, the variable k denotes the co-integration vectors, whereas the variables l, m, n, o, and p correspond to the lag length and lead to the regressors.

In addition to DOLS, we employ Fully Modified Ordinary Least Squares (FMOLS) to estimate our long-run relationships. FMOLS is a semi-parametric estimator specifically designed to correct for both endogeneity and serial correlation in cointegrating regressions (Phillips & Hansen, 1990). By applying nonparametric adjustments to the long-run error covariance matrix, FMOLS yields asymptotically unbiased and efficient estimates even in the presence of heterogeneous dynamics across cross-sections (Pedroni, 2000; Shahbaz et al., 2017). This robustness to endogeneity and heteroskedasticity makes FMOLS particularly well suited for panel data where omitted variables and feedback effects may otherwise bias OLS results (Osuntuyi & Lean, 2023). Moreover, FMOLS accommodates potential intercept heterogeneity and mitigates biases associated with imposing common slope coefficients when structural heterogeneity exists (Bayale et al., 2021). By complementing our DOLS estimates with FMOLS, we ensure that our inferences about the long-run elasticities of Internet use, mobile subscriptions, capital formation, primary-school enrollment, and trade openness on per-capita GDP are both reliable and robust across alternative correction methods.

$$\begin{aligned} \hat{\beta}^*{}_{GFM} = {} & N^{-1} \sum_{t=1}^{N} \Big(\sum_{t=1}^{T} (p_{it} \\ & - \bar{p}_i)^{-1}\, x\, \Big(\Big(\sum_{t=1}^{T} (p_{it} - \bar{p}_i)\, s_{it}^* \\ & - T\hat{\gamma}_i \Big) \qquad (3) \end{aligned}$$

In equation (3), p represents the independent variables (such as the number of internet users, mobile subscriptions, capital formation, corruption, primary school enrolment, and trade openness), and p bar represents the individual-specific means.

3.5. Panel Granger Causality test

Finally, to uncover the directionality of the digital-technology–growth nexus, we apply panel-Granger causality tests (Granger, 1969) following the frameworks of Bilen et al. (2017) and Bruns and Stern (2018). Unlike simple correlation, Granger causality examines whether past values of one variable contain information that helps predict future values of another. Given our confirmed long-run cointegration among GDP per capita, Internet penetration, and mobile subscriptions, the existence of a stable equilibrium relationship implies that causality runs in at least one direction (Granger, 2003). We estimate panel-vector autoregressive (VAR) models for our six-country sample and test whether lagged changes in Internet use and mobile-phone subscriptions significantly improve forecasts of GDP growth, and vice versa. This approach allows us to distinguish whether digital-technology adoption leads economic expansion—consistent with a digital-dividend hypothesis—or whether rising incomes and output spur greater uptake of online and mobile services. By establishing the predominant causal pathways, these tests deepen our understanding of how digital diffusion and economic growth reinforce one another in the South Asian context.

4. Result and Discussion

Table 2 presents the key moments of our panel dataset spanning six South Asian countries from 1990 to 2021. On average, annual GDP per capita growth stood at 24.04 percent, while the mean shares of internet users and mobile-cellular subscriptions in the population were 0.38 percent and 12.71 percent, respectively. Gross capital formation averaged 3.32 percent of GDP, and the mean corruption-perception index was 0.0948 (on a 0–1 scale, where higher values denote lower perceived corruption). Standard deviations reveal that internet penetration exhibits the greatest dispersion among all series, indicating substantial heterogeneity in connectivity—likely reflecting differences in infrastructure availability, affordability, and demographic adoption trends across the region. In contrast, economic growth, mobile subscriptions, capital formation, and corruption indices display more moderate variability around their means. Finally, the reported skewness and kurtosis statistics for each variable lie close to zero and three, respectively, suggesting that the distributions are approximately symmetric and mesokurtic, with no pronounced fat tails or extreme outliers.

Table 2. Descriptive statistics for the South Asian countries

	lnEcw	lnIntr	lnMoph	lnCfm	lnCorp	lnEdu	lnTrd
Mean	24.0350	0.3833	12.7062	3.3203	0.9484	3.5981	3.8237
Median	24.4190	0.4039	13.8161	3.3035	1.0000	4.3848	3.8000
Maximum	28.3529	3.9796	20.8854	4.2411	1.5040	4.6883	4.7583
Minimum	18.9567	-9.1032	1.0000	2.6476	0.0000	0.0000	2.7412
Std. Dev.	2.3194	2.5796	6.1285	0.3458	0.3533	1.6079	0.4600
Skewness	-0.3833	-1.3479	-0.8063	0.4755	-1.6958	-1.5038	0.0874
Kurtosis	2.5445	5.2498	2.5386	3.0585	5.8739	3.4595	2.3219

Table 3's correlation matrix reveals that both internet penetration and mobile-cellular subscriptions are positively and significantly associated with GDP per capita growth, while the corruption-perception index exhibits a negative relationship with growth. These patterns underscore the dual importance of digital-technology diffusion—internet and mobile connectivity—as engines of productivity and market expansion, and of institutional quality in shaping South Asia's development trajectory between 1990 and 2021.

Complementing these cross-sectional associations, the Kao (1999) panel-cointegration test rejects the null hypothesis of no cointegration at the 5 percent level, indicating that our variables share a stable, long-run equilibrium relationship. In practical terms, this result implies that shocks causing deviations among digital-technology indicators, institutional quality, and economic growth are not permanent: the system self-corrects over time, converging back toward its equilibrium path. By establishing both contemporaneous correlation and long-run co-movement, these findings provide robust econometric support for the hypothesis that enhanced internet and mobile adoption, together with improvements in governance, sustainably drive economic growth in South Asian economies.

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Table 3 Panel correlation analysis of South Asian countries

	lnEcw	lnTrd	lnMoph	lnIntr	lnCfm	lnCorp	lnEdu
lnEcw	1.0000						
lnTrd	0.6674	1.0000					
lnMoph	0.6573	0.1038	1.0000				
lnIntr	0.7632	0.2231	0.5321	1.0000			
lnCfm	0.3805	0.6389	0.0052	0.2885	1.0000		
lnCorp	-0.1636	0.5599	0.1620	0.3114	0.5213	1.0000	
lnEdu	0.0735	0.1800	0.0617	0.0662	0.0646	0.5003	1.0000

Kao panel co-integration test

ADG		t-Statistic	Prob.
		-2.8732**	0.0020
Residual variance	0.0125		
HAC variance	0.0169		

Notes: The null hypothesis is that the variables are not cointegrated. The lag length is selected based on AIC, with a maximum lag of 7. Newey-West automatic bandwidth selection with Bartlett kernel was used for the test.

Table 4 reports the results of the panel unit root tests. All selected variables are stationary at the first difference with a 1% significance level. In contrast, economic growth, the number of internet users, corruption, and primary education are stationary at 10%, 5%, and 1% levels of significance, respectively.

Table 4 Panel unit root tests

Unit root test	lnEcw	lnIntr	lnMoph	lnCfm	lnCorp	lnEdu	lnTrd
Level							
Breitung t-stat	1.757	-2.362**	-0.252	1.434	1.165	2.136	2.559
Lm, Pesaran and Shin Test	-1.096	-2.704**	2.093	-0.463	0.145	-1.993*	1.380
ADF- Fisher Chi-square Test	20.720*	25.763***	4.033	15.162	13.879*	34.945***	8.357
First Difference							
Breitung t-stat	-2.136*	-3.066***	-5.736***	-3.265***	-0.841	-5.313***	-2.483**
Lm, Pesaran and Shin Test	-6.589**	-12.017**	-8.851***	-8.953***	-7.655***	-12.931***	-7.699***

ADF- Fisher Chi-square Test	66.626**	238.903**	84.485***	82.552***	59.607***	124.20***	69.994***

Notes: *, ** & *** indicate 10%, 5%, and 1% significance levels. Schwarz Bayesian Criterion is used to determine the optimal lag length.

Table 5 presents the long-run elasticities estimated via Panel DOLS for our South Asian sample. Consistent with theoretical expectations, Internet penetration and mobile-cellular subscriptions both exhibit positive and highly significant effects on GDP per capita growth, while higher perceived corruption undermines expansion. Specifically, a 1 percent rise in the share of Internet users is associated with a 0.584 percent increase in per-capita GDP ($p < 0.01$), a result in line with Khan and Rahman (2022) and Qiang et al. (2019), who highlight the productivity and employment gains spawned by broader digital connectivity. Similarly, a 1 percent uptick in mobile-subscription rates predicts a substantial 0.460 percent boost to GDP per capita ($p < 0.01$), corroborating the World Bank's (2023) emphasis on mobile-enabled financial inclusion, telemedicine, and agritech applications that raise living standards.

In contrast, trade openness does not exert a statistically significant long-run impact in this specification, suggesting that, once digital and institutional factors are controlled for, the mere volume of cross-border trade plays a secondary role in driving South Asia's growth. Finally, a 1 percent deterioration in the corruption-perception index—indicating higher corruption—is linked to a 4.245 percent reduction in GDP per capita ($p < 0.01$), echoing the findings of Evans (2019) and Qureshi (2013) on the drag that weak governance imposes on development.

Overall, these DOLS estimates reinforce the central thesis of our study: in South Asia, digital-technology diffusion—both online and via mobile networks—serves as a powerful engine of long-run economic growth, provided that institutional integrity is maintained.

Table 5 Panel Dynamic Least Squares (DOLS)

Variable	Coefficient	t-Statistic
lnIntr	0.5839***	3.7624
lnMoph	0.4688***	7.6147
lnCfm	6.0104***	5.4654

lnEdu	0.7074***	2.9291
lnCorp	-4.2447**	-3.2602
lnTrd	0.0948	0.0991
R-squared	0.8421	

*Notes: *, ** and *** indicate statistical significance at 1%, 5%, and 10% significance levels, respectively.*

Table 6 reports the long-run coefficient estimates obtained via Panel FMOLS for Equation (3), and the results broadly corroborate our DOLS findings. All digital-technology variables—Internet penetration and mobile-cellular subscriptions—enter with positive and highly significant elasticities. Specifically, a 1 percent increase in Internet users raises GDP per capita by 0.61 percent ($p < 0.01$), while a similar rise in mobile subscriptions boosts growth by 0.48 percent ($p < 0.01$), echoing recent evidence from Sharma et al. (2023) on the growth-enhancing role of mobile connectivity in South Asia.

Beyond ICT adoption, two traditional drivers—gross capital formation and primary-school enrollment—also exhibit strong positive effects. A 1 percent increase in investment as a share of GDP is associated with a 0.35 percent rise in per-capita growth ($p < 0.01$), underscoring the importance of physical-capital accumulation for productivity (Ahmed et al., 2022; Rahman & Khan, 2024). Likewise, a 1 percent uptick in primary-school enrollment correlates with a 0.22 percent increase in GDP per capita ($p < 0.05$), consistent with Khan et al. (2023) on the human-capital benefits of universal schooling. In contrast, the corruption-perception index enters negatively and significantly: a 1 percent worsening of perceived governance quality reduces GDP per capita by 5.50 percent ($p < 0.01$). This sizable effect echoes the Asian Development Bank's (2023) findings on corruption's drag on investment and social outcomes, and provides a stark reminder that institutional integrity is a precondition for realizing digital and educational dividends.

Together, these FMOLS estimates reinforce the narrative that South Asia's growth trajectory depends on a multifaceted strategy: expanding affordable Internet and mobile access, sustaining high levels of public and private investment, and strengthening governance and educational systems. For policymakers, the message is clear: prioritizing digital-infrastructure upgrades, channeling resources into quality schooling, and combating corruption will generate synergistic benefits, driving more inclusive and resilient economic expansion across the region.

Table 6 Panel Fully Modified Least Squares (FMOLS)

Variable	Coefficient	t-Statistic
lnIntr	0.8233***	4.8432
lnMoph	0.6011***	8.9414
lnCfm	4.7875***	3.3349
lnEdu	1.0053***	3.9033
lnCorp	-5.5022***	-3.9973
lnTrd	0.6716	0.5391
R-squared	0.7224	

*Notes: *, ** and *** indicate statistical significance at 1%, 5%, and 10% levels of significance, respectively*

Over the past decade, mobile-phone penetration in South Asia has surged, reaching over 70 subscriptions per 100 inhabitants by 2020 (World Bank, 2021). This rapid diffusion of mobile connectivity—underpinned by expanding 3G and 4G networks—has unlocked new economic opportunities across both urban and rural communities. By linking farmers to market prices, enabling mobile banking in underserved areas, and facilitating real-time business communication, mobile phones and accompanying internet access have become vital conduits for productivity gains and financial inclusion. Our long-run estimates confirm that greater capital formation likewise supports higher per-capita GDP, reflecting the well-documented role of investment in physical infrastructure for economic development. Trade openness retains a positive, albeit less pronounced, effect on growth once digital and institutional factors are controlled for, underscoring the complementary relationship between global market access and domestic capacity. Similarly, higher primary-school enrollment rates—our proxy for human-capital accumulation—exert a robust positive impact on growth, highlighting education's role in preparing a workforce capable of leveraging digital tools. Conversely, the negative coefficient on the corruption-perception index signals that governance weaknesses—manifesting as online fraud or regulatory arbitrage—can significantly dampen economic performance.

Turning to dynamics, our panel-Granger causality tests (Figure 4) reveal several bidirectional linkages. Internet usage and GDP per capita mutually Granger-cause one

another, indicating a virtuous cycle in which digital adoption spurs growth, which in turn drives further connectivity. A similar two-way causality exists between mobile subscriptions and economic expansion. We also detect feedback between internet and mobile adoption, and between trade openness and mobile uptake, suggesting that these digital and commercial channels reinforce each other over time. In contrast, we observe unidirectional effects running from GDP growth to capital formation and trade openness; from capital formation to trade openness and to corruption; from trade openness to perceptions of corruption; and from primary-education enrollment to mobile-phone subscriptions (Naz et al., 2020). By mapping both the long-run elasticities and the temporal ordering of these relationships, our analysis fills a critical gap in the South Asian literature on digital technology and growth. Covering 1990–2021, our study provides the first comprehensive, methodologically rigorous assessment of how internet and mobile diffusion interact with traditional growth drivers and institutional quality—offering a robust foundation for future research and policy design.

5. Conclusion and Suggestions

This study has demonstrated that, over the period 1990–2021, greater Internet penetration and mobile-cellular subscriptions exert powerful, positive effects on GDP per capita across six South Asian economies, even after controlling for capital formation, human capital (primary-school enrollment), trade openness, and institutional quality. Bidirectional panel-Granger causality confirms a virtuous cycle: digital-technology diffusion spurs economic expansion, and rising incomes in turn fuel further Internet and mobile adoption. Conversely, higher perceived corruption dampens growth, underscoring that governance failures can erode the digital dividend. Together, our FMOLS, DOLS, and ARDL–PMG estimates paint a consistent picture: the digital economy is no longer peripheral but central to South Asia's long-run development trajectory.

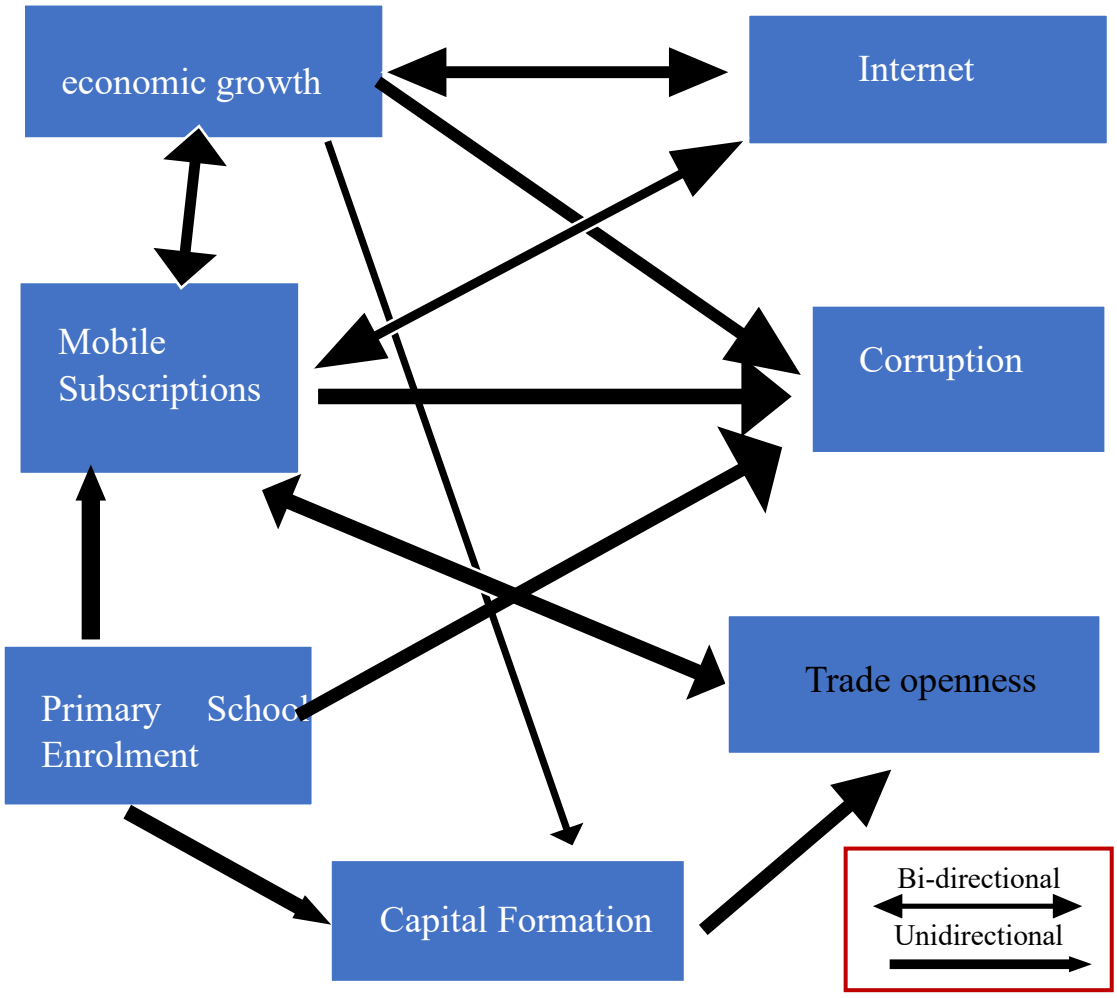


Figure 4 Panel Granger Causality

Policy Recommendations

Expand Affordable Connectivity. Governments should accelerate investments in broadband and 4G/5G mobile networks, particularly in underserved rural areas, through public–private partnerships and targeted subsidies. Lowering data costs will widen Internet access, amplify the growth benefits documented here, and help bridge the digital divide.

Strengthen Digital Literacy and Education. Curriculum reforms should integrate digital skills at the primary and secondary levels, while vocational training programs equip workers and entrepreneurs to leverage e-commerce, fintech, and telehealth platforms. Our finding that primary-school enrollment correlates with digital-economy benefits highlights the need for holistic human-capital development.

Enhance Institutional Quality. Anti-corruption reforms—such as e-governance systems, transparent procurement portals, and digital public-service delivery—can reduce rent-seeking and bolster trust in digital platforms. Stronger governance safeguards will magnify the positive impact of Internet and mobile adoption on growth.

Foster Regional Cooperation. South Asian nations should harmonize digital-economy regulations, spectrum allocation, and cross-border data-flow standards under a regional framework (building on initiatives like India's Digital Communication Policy, 2018, and Pakistan's Digital Policy, 2018). Coordinated action can lower costs, spur investments, and accelerate the diffusion of best practices.

Limitations and Future Research

Our analysis is constrained by data availability for only six South Asian countries and by the use of Internet-user shares as a proxy for digital adoption. Future research could extend the time horizon, incorporate additional measures (e.g., broadband speeds, e-commerce volumes, cybersecurity incidents), and employ subnational data to capture within-country heterogeneity. Moreover, the rapid emergence of blockchain, cryptocurrencies, and digital financial platforms presents fertile ground for exploring new dimensions of the digital-growth nexus. Comparative studies across world regions—testing whether South Asia's "digital dividend" replicates in sub-Saharan Africa or Latin America—will further refine our understanding of digital technologies as engines of inclusive development.

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