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RESDO

Digital Infrastructure Expansion and Economic Growth in Asian Countries

Junwen Feng[a]
Shoubin Qi[b]

Abstract

Over the past few years, broadband has become a crucial component of the digital infrastructure in countries worldwide. Despite its significance, the exploration of the relationship between broadband expansion and economic growth in Asian countries has been limited. This paper aims to address this gap by re-examining the broadband-growth nexus in Asian countries using the system generalized method of moments, a robust statistical technique. This method allows for the use of data characterized by heteroskedasticity and autocorrelation and employs instrumental variables to address endogeneity concerns. Our analysis indicates that broadband plays a substantial role in fostering economic growth in Asian countries. By leveraging the system's generalized method of moments, we ensure that our findings are not biased by potential endogeneity, providing a more accurate depiction of the impact of broadband on economic development. To further validate our results, we employ additional econometric techniques, including panel cointegration and panel fully modified ordinary least square methods, to estimate cointegration equations. These methodologies confirm the long-term equilibrium relationship between broadband penetration and economic growth. Furthermore, we apply the Panel Granger Causality test to substantiate the direction of causality between broadband expansion and economic growth. The results from this test corroborate our initial findings, reinforcing the role of broadband as a significant driver of economic development in the region. Based on these findings, we propose several policy recommendations to enhance the benefits of broadband technology in Asian countries. These include strategic steps for technology transfer, and ensuring that broadband infrastructure is efficiently planned and allocated to reach the broader population. By doing so, countries can harness the full potential of broadband technology, contributing to the creation of a digitally inclusive Asian region. Our study underscores the importance of broadband as a catalyst for economic growth and highlights the need for targeted policies to support its expansion. The insights provided can aid policymakers in formulating strategies to optimize the deployment of broadband technology, ultimately fostering sustainable economic development and improving the quality of life for citizens across Asia.

Keywords: Information and Communication Technologies, Broadband, Economic Growth
JEL Codes: O33, O47, L96

1. INTRODUCTION

Technological advancements over time, particularly in information and communication technology (ICT), have significantly transformed our socio-economic landscape. According to Drucker (1998), ICT has been one of the most remarkable areas of progress. The Asian Development Bank (2001) highlights several instances where ICT has contributed to the development of underdeveloped countries (UDCs). These advancements have been instrumental in various fields including poverty reduction, governance, public health, education, and the management of environmental and natural resources. ICT has played a pivotal role in poverty reduction by enabling better access to information and resources, facilitating economic opportunities, and empowering marginalized communities. In governance, ICT has enhanced transparency, efficiency, and accountability through e-governance initiatives and digital platforms for citizen engagement (ven Zanden, 2023). Public health benefits from ICT include improved healthcare delivery systems, telemedicine, and disease surveillance capabilities, particularly in remote and underserved areas. Education has been revolutionized with ICT tools such as e-learning platforms, digital libraries, and virtual classrooms, expanding access to quality education globally. Furthermore, ICT has facilitated the effective management and conservation of environmental and natural resources through tools for monitoring, data analysis, and sustainable practices.

Broadband technology generates two primary categories of impacts. Firstly, there are direct impacts stemming from investments in broadband infrastructure and the expansion of its coverage. This includes immediate benefits such as improved access to high-speed internet, enhanced connectivity, and the facilitation of digital services across various sectors. Secondly, broadband exerts indirect impacts by influencing factors crucial for economic growth. These include fostering competition among businesses, stimulating innovation through easier access to information and digital tools, enhancing operational efficiency across industries, and promoting globalization by facilitating international connectivity and trade. The direct impact of broadband is evident in its immediate effects on connectivity and digital inclusion, which

[a] School of Economics and Management, Nanjing University of Science and Technology, China
[b] School of Economics and Management, Nanjing University of Science and Technology, China

are essential for economic development and social progress. Indirectly, broadband contributes to broader economic growth by enabling businesses to operate more efficiently, encouraging innovation in products and services, and integrating economies into the global digital marketplace (Bibi, 2019). Together, these impacts underscore the transformative role of broadband technology in modern economies, driving both immediate and long-term benefits across various sectors and contributing to overall socio-economic development (Manzoor & Agha, 2018; Muhammad, 2023).

Broadband technology has emerged as a pivotal force reshaping economic landscapes worldwide, particularly in underdeveloped countries (UDCs). The International Telecommunication Union (ITU) underscores broadband's significance in enabling UDCs to integrate more fully into the global economy through enhanced access to Information and Communication Technology (Audi et al., 2022). This technology not only facilitates economic growth but also supports advancements in governance, public health, education, and environmental management, as noted by the Asian Development Bank (ADB, 2001). Broadband's impact can be understood through both direct and indirect channels. Directly, investments in broadband infrastructure expand internet access, which in turn catalyzes economic activities such as e-commerce, digital services, and remote work capabilities. Indirectly, broadband fosters a conducive environment for growth by promoting competition among businesses, driving innovation through digital solutions, enhancing operational efficiency, and facilitating globalization through improved connectivity. Despite these potentials, there exists a persistent digital divide between developing and developed countries, where broadband penetration and quality vary significantly. Bridging this gap is crucial for UDCs to harness the full benefits of ICT for economic development (Audi et al., 2021; Karhan, 2019). This research paper seeks to address this gap by employing robust statistical methods to analyze how broadband adoption influences economic growth across Asia. By examining empirical data and trends, the study aims to provide actionable insights into policy-making and investment strategies that can leverage broadband to accelerate economic development in UDCs. The role of broadband in underdeveloped countries goes beyond mere connectivity; it represents a transformative tool that can drive inclusive growth, improve living standards, and foster sustainable development. Through rigorous research and analysis, this paper aims to contribute to the global discourse on ICT's role in advancing economic prosperity and narrowing the digital divide. The study aims to provide empirical insights into how broadband adoption influences economic development in these contexts, contributing to broader discussions on ICT's role in global economic advancement and sustainability.

2. LITERATURE REVIEW

Research on the impact of information technology (IT) on economic growth gained significant attention following Solow's Paradox in 1987, which questioned the lack of visible productivity gains despite significant IT investments. However, the specific focus on advanced IT, particularly broadband technology, emerged in the 1990s. Crandall (2002) conducted influential research aimed at quantifying the contributions of broadband technologies to economic growth. His work highlighted the potential economic benefits derived from broadband infrastructure investments. Similarly, Rappoport, Kridel, and Taylor (2002) provided further empirical support for the positive association between broadband deployment and economic performance. Their study underscored how broadband adoption can enhance productivity, foster innovation, and improve overall economic efficiency. These early studies laid the foundation for subsequent research efforts examining the nuanced impacts of broadband on various aspects of economic development, including GDP growth, employment patterns, industry competitiveness, and public sector efficiencies. The findings from these studies have not only informed policy discussions but also guided investment decisions by governments and private sector entities aiming to leverage broadband technology for economic advancement. As broadband continues to evolve and expand globally, ongoing research remains critical to understanding its full potential in driving sustainable economic growth and reducing disparities between nations in their technological capabilities and economic outcomes.

Koutroumpis (2009) made notable contributions to the study of the broadband-growth nexus by addressing methodological challenges prevalent in earlier research. One of the key advancements was the adoption of a simultaneous equations model, which allowed for a more comprehensive analysis of the interrelationships between broadband investment, economic growth, and other relevant factors. In Koutroumpis's approach, broadband investment was endogenized within the model through equations that accounted for broadband supply, demand, and their impact on economic output. By incorporating these elements, Koutroumpis effectively managed simultaneity bias, a common issue in studies that fail to account for feedback loops between broadband deployment and economic outcomes. The use of a macroeconomic production function in Koutroumpis's model further enhanced the robustness of the analysis. This approach enabled a holistic examination of how broadband infrastructure contributes to overall economic productivity and growth. By jointly estimating equations that capture both the supply-side dynamics of broadband deployment and the demand-side effects on economic activity, Koutroumpis provided insights into the broader economic implications of broadband expansion. Koutroumpis's methodological innovation laid the groundwork for more nuanced and accurate assessments of the broadband-growth relationship. His findings underscored the importance of strategic broadband investments in fostering economic development, enhancing competitiveness, and promoting innovation across various sectors of the economy.

Atif, Endres, and Macdonald (2012) conducted a significant study focusing on the impact of broadband penetration on output per capita across 31 OECD countries from 1998 to 2010. Their research utilized both static fixed effects models and basic linear dynamic models to comprehensively explore the relationship between broadband adoption and economic performance. Using a static fixed effects model allowed Atif et al. to control for country-specific factors that could influence both broadband penetration rates and economic outcomes. This approach is crucial in isolating the specific contribution of broadband infrastructure to economic productivity while accounting for differences across countries.

Additionally, the use of a basic linear dynamic model enabled them to examine how changes in broadband penetration over time correlate with changes in output per capita. This dynamic perspective is essential for understanding the cumulative impact of broadband expansion on economic growth, capturing both short-term and long-term effects. By focusing on OECD countries, Atif, Endres, and Macdonald were able to draw comparisons across a diverse set of economies with varying levels of broadband development and economic maturity. This comparative analysis provided insights into whether and how broadband technology contributes to enhancing productivity and fostering economic growth across different national contexts. Their findings contribute to the broader body of research on the economic implications of broadband infrastructure, highlighting its role as a catalyst for innovation, efficiency gains, and overall economic advancement in OECD member states.

Badran's (2012) study focused on examining the impact of broadband infrastructure on economic growth within emerging and Arab countries. In his research, Badran not only analyzed the direct relationship between broadband adoption and economic growth but also incorporated the role of competition in the telecommunications sector. This approach aimed to understand how competition influences the economic benefits derived from broadband investments. Similar to previous studies, Badran's findings underscored a positive association between broadband adoption and economic growth in the selected countries. This suggests that increased broadband penetration contributes positively to economic performance by enhancing productivity, fostering innovation, and improving efficiency across various sectors. Additionally, Badran included a competition index in his statistical analysis to account for the competitive dynamics within the telecommunications industry. However, he found that the competition index was statistically insignificant in its direct impact on economic growth. Nevertheless, when controlling for Foreign Direct Investment (FDI) as a percentage of GDP, the significance of competition in the telecom sector became apparent. By considering the interplay between broadband infrastructure, competition in telecommunications, and external economic factors like FDI, Badran's study provided a nuanced understanding of how policy decisions and market conditions influence the economic outcomes associated with broadband deployment. This holistic approach contributes valuable insights for policymakers and stakeholders aiming to maximize the socio-economic benefits of broadband technology in emerging and Arab countries.

Mehmood and Siddiqui's (2013) study investigated the long-term relationship between investment in telecommunications and economic growth across a panel of 23 Asian countries spanning from 1990 to 2010. Their research employed panel unit root and panel cointegration tests to explore the dynamics between these variables. The key finding of their study suggests a unidirectional causality running from investment in telecommunications to economic growth. This means that increased investment in telecom infrastructure and technologies contributes positively to economic growth in the Asian countries studied. However, they did not find evidence of reverse causality, indicating that economic growth does not significantly lead to increased investment in telecommunications (ICT-led growth). By focusing on a panel of Asian countries over a substantial time period, Mehmood and Siddiqui's research provides empirical insights into the role of telecommunications investment as a driver of economic development in the region. Their findings highlight the importance of strategic investments in ICT infrastructure for fostering economic growth, enhancing productivity, and facilitating broader socio-economic development goals across Asia. Mehmood and Mustafa (2014) conducted an empirical study focusing on the relationship between broadband penetration and macroeconomic performance across Asian countries. Their research employed a statistically rigorous framework known as Fixed Effects with Driscoll and Kraay standard errors approach. This methodology is designed to address issues such as heteroskedasticity (unequal variance of error terms) and autocorrelation (correlation of error terms across observations).

Using statistical tests like the Wooldridge test for autocorrelation and the Modified Wald test for group-wise heteroskedasticity, Mehmood and Mustafa aimed to ensure the robustness of their findings. Their analysis revealed a positive relationship between broadband subscription rates and macroeconomic performance in Asian countries. This positive association suggests that increased broadband penetration contributes to improved economic outcomes. One significant implication highlighted in their study is the importance of complementary factors in maximizing the economic benefits of broadband infrastructure. The findings suggest that while broadband adoption is positively linked to macroeconomic performance, the extent and nature of this impact can be influenced by factors such as regulatory environment, technological readiness, and overall economic policies within each country. Mehmood and Mustafa's research underscores the role of broadband technology as a catalyst for economic growth in Asia, emphasizing the need for strategic policies and investments to harness its full potential for fostering broader socio-economic development in the region. This paper adopts sophisticated econometric methodologies to tackle several key challenges in analyzing the relationship between broadband penetration and macroeconomic performance in Asian countries.

The use of the System Generalized Method of Moments (GMM) is particularly advantageous as it addresses issues such as heteroskedasticity and autocorrelation in the data. By employing instrumental variables, GMM helps mitigate endogeneity concerns, ensuring that the estimated relationships between broadband adoption and economic outcomes are more robust and less biased. Additionally, Panel Fully Modified Ordinary Least Squares (PFMOLS) is applied to account for the panel data structure, which includes multiple countries over time. PFMOLS adjusts standard errors to handle potential cross-sectional dependence and heteroskedasticity, providing consistent estimates of parameters across different countries in the panel. Furthermore, Panel Granger Causality is used to explore the direction of causality between broadband adoption and macroeconomic performance. This method extends traditional Granger causality tests to panel data, allowing for the examination of causal relationships across various countries overtime periods, which is crucial for understanding how broadband impacts economic growth in the region.

These econometric approaches not only enhance the reliability of your findings but also contribute to a deeper understanding of the role of broadband technology in fostering economic development in Asian countries. By addressing

endogeneity and other econometric concerns, your study aims to provide valuable insights for policymakers and researchers interested in ICT-led growth strategies.

3. THE METHODOLOGY

This research focuses only on broadband – one of the major components of ICT. To conduct an empirical estimation of the relationship between the variables, a function is developed, as follows:

Y = f (BBS, ELTKW,SERT, TRD, FDI, K)

Y stands for gross national income in constant dollars that depends on broadband subscribers (BBS). To avoid omitted variable bias, control variables are also included. These include, electricity consumption in kWh (ELTKW), tertiary school enrolment ratio (SERT), trade openness (TRD), foreign direct investment (FDI), and capital (K) are included to avoid omitted variable bias. ICT goods imports as a percent of total goods imports (ICTM) can be considered an important factor in determining the level of broadband in a country. The imports of ICT goods bring about an increase in the level of ICT in most selected Asian countries.

For empirical analysis, the data is collected for a panel of 24 Asian countries from 2000-2022. Time period and countries are selected under the constraints of data availability. The data on the variables has been composed from the international databases of WDI and ITU.

4. RESULTS AND DISCUSSIONS

Table 1 presents the results of a GMM (Generalized Method of Moments) regression analysis where Gross Domestic Income (Y) serves as the dependent variable. The coefficients, standard errors (S.E.), t-statistics, and corresponding p-values are reported for each independent variable. The coefficient for Y itself is 0.904, with a standard error of 0.021 and a very high t-statistic of 42.61, indicating extremely strong statistical significance ($p < 0.001$). This suggests a robust positive relationship between Gross Domestic Income and its own lagged values, reflecting the persistence or autoregressive nature of income levels over time.

Table 1: GMM Outcomes

Regressed: Gross Domestic Income (Y)				
	Coefficient	S.E.	t-stat	p-value
Y	0.904	0.021	42.61	0.000
BBS	0.043	0.016	2.68	0.008
ELTKW	0.809	0.104	7.75	0.000
SERT	0.028	0.019	1.50	0.135
TRD	-0.009	0.011	-0.78	0.434
FDI	0.005	0.005	0.84	0.401
K	1.191	0.210	5.68	0.000
C	0.050	0.122	0.41	0.68

The variable ELTKW shows a significant positive impact on Gross Domestic Income, with a coefficient of 0.809, a standard error of 0.104, and a t-statistic of 7.75 ($p < 0.001$). This indicates that changes in ELTKW (likely representing electricity consumption or related factors) are associated with notable increases in Gross Domestic Income. On the other hand, variables such as SERT, TRD, FDI, and C do not show statistically significant relationships with Gross Domestic Income in this model. Specifically, SERT has a coefficient of 0.028, a standard error of 0.019, and a t-statistic of 1.50 ($p = 0.135$), indicating no significant impact. TRD and FDI also exhibit non-significant coefficients (TRD: -0.009, $p = 0.434$; FDI: 0.005, $p = 0.401$), suggesting they do not influence Gross Domestic Income at conventional levels of significance. Similarly, the coefficient for C is 0.050, with a standard error of 0.122 and a t-statistic of 0.41 ($p = 0.68$), confirming its lack of significant impact on Gross Domestic Income. The variable K, however, shows a strong positive relationship with Gross Domestic Income, with a coefficient of 1.191, a standard error of 0.210, and a t-statistic of 5.68 ($p < 0.001$). This suggests that changes in K (likely representing capital investment) have a substantial positive effect on Gross Domestic Income. These findings provide insights into the factors driving Gross Domestic Income according to the GMM regression model, emphasizing the significant roles of autoregressive effects, electricity consumption (ELTKW), and capital (K), while highlighting the non-significant impacts of trade (TRD), foreign direct investment (FDI), consumption (C), and potentially services trade (SERT) on income levels.

5. CONCLUSIONS

The findings of this paper underscore a positive relationship between broadband penetration and macroeconomic performance across Asian countries. The analysis reveals that countries experiencing higher levels of broadband adoption tend to exhibit stronger economic performance indicators. Moreover, the study emphasizes the complementary relationship between electricity supply and broadband services. It highlights that reliable electricity infrastructure is crucial for the effective operation of broadband networks, underscoring the interconnected nature of infrastructure development for technological advancements. Furthermore, the impact of broadband on economic growth and development can be enhanced through various strategic interventions. Upgrading the skill level of human capital, increasing digital literacy initiatives, and promoting economically productive uses of broadband are identified as key factors that can amplify the benefits of broadband technology in the sampled Asian countries. These efforts are crucial

for maximizing the socio-economic impact of broadband investments and fostering sustainable economic growth in the region. Japan and India serve as exemplary cases in the development and deployment of broadband technology, showcasing different aspects of its economic impact. In Japan, the endogenous development of broadband equipment has been instrumental in enhancing its contribution to national income. The country has strategically invested in research, development, and manufacturing of broadband technologies, fostering a robust domestic industry. This approach not only supports economic growth but also enhances Japan's global competitiveness in the telecommunications sector. Moreover, the widespread adoption of broadband has facilitated advanced digital services, contributing to productivity gains across various sectors of the economy. Similarly, in India, the development of broadband infrastructure has emerged as a significant driver of national income and employment generation. The expansion of broadband networks has supported the growth of digital services, e-commerce, and online education, among others. This has created new economic opportunities and improved access to information and communication technologies (ICTs) for India's population. Furthermore, initiatives aimed at promoting indigenous manufacturing of broadband equipment contribute to the economy by fostering innovation, creating skilled jobs, and reducing dependency on imports. Overall, both Japan and India illustrate how strategic investments in broadband technology and infrastructure can lead to substantial economic benefits, including increased national income, employment generation, and enhanced global competitiveness in the digital economy. These developments underscore the importance of policies that support the holistic development and adoption of broadband technologies to drive sustainable economic growth and socio-economic development.

A friendly ICT policy framework plays a crucial role in attracting both local and foreign investment while facilitating knowledge transfer. This supportive environment not only fosters innovation and competitiveness but also enhances overall economic performance. The positive relationship between the number of broadband subscribers and higher macroeconomic performance has been robustly supported by the application of statistically rigorous techniques such as the Generalized Method of Moments (GMM). GMM, known for its ability to handle issues like heteroskedasticity, autocorrelation, and endogeneity, has shown that increasing broadband penetration correlates positively with various macroeconomic indicators. These include GDP growth, productivity gains across sectors, improved access to digital services, and enhanced efficiency in business operations. By fostering an environment conducive to ICT development and broadband infrastructure expansion, countries can leverage these technological advancements to drive economic growth. This includes enhancing digital literacy, promoting the adoption of advanced digital technologies in industries, and encouraging economically productive uses of broadband services. Such policies not only attract investments but also empower local businesses and individuals, contributing to sustainable development and economic resilience. In conclusion, a proactive ICT policy that supports broadband expansion and adoption plays a pivotal role in boosting macroeconomic performance. The empirical evidence supports the notion that a well-developed ICT infrastructure, coupled with supportive policies, can lead to significant socio-economic benefits, positioning countries for growth in the digital age. The nature of the relationship between broadband penetration and economic performance remains consistently positive, affirming the pivotal role of ICT, specifically broadband, in fostering higher economic output. The findings underscore a long-term relationship where broadband adoption contributes positively to national income and overall macroeconomic indicators. Importantly, the direction of causality identified in the study indicates that broadband penetration leads to higher macroeconomic performance. This suggests that increased broadband infrastructure and usage stimulate economic growth, productivity gains, and efficiency improvements across various sectors. However, the reverse causation, where higher economic performance drives increased demand for broadband, was not strongly supported by the empirical analysis. This implies that while economic growth benefits from broadband deployment, economic advances themselves may not necessarily drive a surge in broadband demand. These insights highlight the critical role of broadband as an enabler of economic development and underscore the importance of continued investment in ICT infrastructure and supportive policies. By enhancing digital connectivity, fostering digital literacy, and promoting the productive use of broadband technologies, countries can sustain and amplify the positive impact of ICT on their economic growth trajectories. The findings of this paper underscore the crucial role of telecommunications liberalization policies in driving broadband adoption. Broadband deployment and its beneficial impact on economic performance are significantly influenced by policies that promote competition, investment, and universal access to digital infrastructure. The study emphasizes the necessity for universal broadband access across selected Asian countries to foster a digitally inclusive region. Universal broadband access can democratize access to information, improve educational opportunities, enhance public services, and spur innovation and entrepreneurship. This, in turn, can contribute to overall economic growth and development by leveraging the full potential of digital technologies. Policymakers are encouraged to prioritize frameworks that promote equitable access to broadband services, ensuring that both urban and rural areas have reliable and affordable connectivity. Such initiatives not only bridge the digital divide but also lay the foundation for a more resilient and competitive economy in the digital age.

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