Jurnal Kebijakan Ekonomi dan Keuangan
Available at https://journal.uii.ac.id/jkek

Digital infrastructure quality and stock market development: Evidence from panel data with the conditional role of FDI

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JEL Classification Code: G10, O33, F21

Keywords: Digital Infrastructure Quality; High-Technology Exports; Stock Market Capitalization; FDI

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DOI:
10.20885/JKEK.vol5.iss1.art1

Abstract

Purpose – *This study examines the impact of digital infrastructure quality on stock market capitalization and evaluates the moderating role of foreign direct investment (FDI).*

Methods – *Using panel data from 10 countries over the period 2012–2023, the study employs random effects estimation with robust standard errors to ensure consistency under heteroskedasticity.*

Findings – *The results show that fixed broadband significantly enhances stock market capitalization, while internet usage is statistically insignificant. High-technology exports exhibit a negative association with market capitalization, whereas FDI contributes positively and its interaction with digitalization indicates a declining marginal effect of internet usage at higher levels of FDI.*

Implication *– This finding emphasizes that digital quality is more important than access alone in promoting financial market development.*

Originality – *This study advances the literature by focusing on digital infrastructure quality rather than digital adoption and by providing new cross-country evidence on the joint roles of digitalization, FDI, and high-technology exports in stock market development*

Abstrak

Tujuan – Penelitian ini menganalisis pengaruh kualitas infrastruktur digital terhadap kapitalisasi pasar saham serta peran moderasi investasi asing langsung (FDI).

Metode – Penelitian menggunakan data panel dari 10 negara pada periode 2012–2023 dengan pendekatan random effects dan robust standard errors untuk meningkatkan ketahanan estimasi.

Temuan – Hasil penelitian menunjukkan bahwa fixed broadband berpengaruh positif dan signifikan terhadap kapitalisasi pasar saham, sementara penggunaan internet tidak signifikan. Ekspor teknologi tinggi berhubungan negatif dengan kapitalisasi pasar, sedangkan FDI berkontribusi positif dan efek marginal penggunaan internet cenderung menurun pada tingkat FDI yang lebih tinggi.

Implikasi – Temuan ini menekankan bahwa kualitas digital lebih penting dibandingkan akses semata dalam mendorong perkembangan pasar keuangan.

Orisinalitas – Studi ini memperkaya literatur dengan berfokus pada kualitas infrastruktur digital, bukan sekadar adopsi digital, serta memberikan bukti lintas negara mengenai peran digitalisasi, FDI, dan ekspor teknologi tinggi dalam mendorong perkembangan pasar saham.

Introduction

Financial markets play a critical role in mobilizing savings, allocating capital, and supporting long-term economic growth. Among the various indicators of financial development, stock market capitalization is widely used to capture the size and depth of equity markets and their ability to facilitate investment and capital formation (Levine, 2004). As economies become increasingly digitalized, the development of digital infrastructure has emerged as an important factor shaping financial market performance. Digital technologies reduce information costs, improve market transparency, facilitate financial transactions, and expand investor participation, thereby strengthening the functioning of capital markets.

The positive effect of fixed broadband subscriptions may be explained by the role of high-quality digital infrastructure in reducing information frictions and improving market efficiency. Broadband networks facilitate faster access to financial information, enhance communication between market participants, and lower information-processing costs, thereby encouraging investor participation and supporting market expansion. This argument is consistent with Information Economics Theory (Akerlof, 1970) and with the findings of (Blankespoor et al., 2020), who emphasize that reductions in information-processing costs improve market liquidity and pricing efficiency. Similarly, (Farboodi & Veldkamp, 2020) argue that advances in financial data technology reduce information costs, increase market participation, and enhance financial market liquidity, ultimately contributing to deeper capital markets.

Recent empirical evidence generally supports the positive role of digitalization in financial development. Using cross-country data, (Nguyen et al., 2020) found that internet and mobile connectivity contribute positively to financial development through improved access to financial services and information. Similar evidence is provided by (Bayar et al., 2021), who find that internet and mobile-phone usage enhance financial inclusion by expanding access to financial services and increasing participation in financial activities. Similarly, (Igwilo & Sibindi, 2022) reported that information and communication technology adoption promotes stock market development in African economies. Moreover, (Sassi & Goaied, 2013) show that the economic benefits of financial development are strengthened when ICT diffusion reaches higher levels, suggesting that the impact of digitalization may depend on complementary structural conditions. More recently, (He et al., 2024) demonstrated that digital infrastructure improvements significantly enhance financial depth and efficiency, while (Li et al., 2024) showed that the financial benefits of digital technologies vary across countries according to structural conditions. At the microeconomic level, (Feng et al., 2025) found that internet usage increases household participation in financial markets by reducing information and participation costs. Likewise, (Firmansyah et al., 2025) documented that digitalization strengthens portfolio investment flows through improved transparency and investor confidence.

The growing literature also highlights the importance of information quality as a channel through which digitalization influences financial markets. Consistent with Information Economics Theory, (Ma et al., 2024) show that greater public data availability improves information transparency and reduces stock price crash risk by strengthening external monitoring mechanisms. Similarly, (Li et al., 2024) find that digitalization enhances stock price informativeness by reducing information asymmetry, lowering agency costs, and improving investment efficiency. (Shu, 2024) further demonstrates that digital communication improves information diffusion and market efficiency, while (Zhang et al., 2024) report that digitalized firms achieve higher market valuation and greater resilience during economic shocks. Collectively, these findings suggest that digital infrastructure affects financial markets not only through technological access but also through substantial improvements in the informational environment.

Alongside digitalization, foreign direct investment (FDI) remains one of the most important external drivers of financial development. According to (Alfaro et al., 2004), the benefits of FDI depend on the absorptive capacity of domestic financial systems. FDI contributes capital, technology transfer, managerial expertise, and international business networks that can stimulate financial market development. Empirical evidence generally supports this view. (Chettri & Bhattarai, 2023) find that FDI contributes positively to stock market development in Nepal, while

(Haruna et al., 2023) demonstrate that the positive effect of FDI on stock markets depends on regulatory quality, indicating that institutional conditions influence the effectiveness of foreign investment. These findings suggest that foreign investment can support stock market development when supported by favourable domestic conditions and effective financial systems.

Recent studies suggest that digitalization may shape how economies absorb and benefit from foreign investment. (Rizaldi & Jayadi, 2022) find that improvements in digital infrastructure attract greater FDI inflows by reducing information and transaction costs, while (Mai, 2025) reports that digital readiness enhances a country's attractiveness to foreign investors. Consistent with Financial Development Theory, digital infrastructure can strengthen financial markets by improving information flows, reducing transaction costs, and expanding market access (Levine, 2004). Moreover, the FDI–financial development framework of (Alfaro et al., 2004) argues that foreign investment promotes financial development through capital accumulation, technology transfer, and managerial spillovers. Supporting this view, (Santosa et al., 2025) and (Supriyanto et al., 2025) show that digitalization strengthens the economic benefits of foreign investment. Together, these findings suggest that digital infrastructure and FDI may operate as complementary forces in promoting stock market development.

Despite increasing scholarly attention, important gaps remain. Existing studies largely focus on broader economic and financial outcomes rather than stock market capitalization, often examine digitalization and FDI separately, and rely on narrow digitalization measures such as internet usage. Moreover, limited cross-country evidence exists on whether digital infrastructure quality moderates the relationship between FDI and stock market development (Dwi Abdulah Rusli Suseno, 2025; He et al., 2024; Igwilo & Sibindi, 2022; Babarinde, 2025; Haruna et al., 2023; Santosa et al., 2025; Supriyanto et al., 2025).

Existing empirical studies consistently suggest that digitalization contributes to financial development, although important gaps remain in the literature. Nguyen et al. (2020) demonstrated that digital connectivity promotes financial development but did not specifically examine stock market capitalization. Similarly, Igwilo and Sibindi (2022) found that ICT adoption supports stock market development; however, their analysis did not consider the role of foreign direct investment (FDI). Haruna et al. (2023) showed that FDI promotes stock market development under favorable institutional conditions but did not incorporate digital infrastructure into their analysis. More recently, He et al. (2024) reported that digital infrastructure enhances financial development, although their study did not focus specifically on stock market capitalization. Likewise, Santosa et al. (2025) demonstrated that digitalization strengthens the economic benefits of FDI but did not investigate its implications for stock market development. Taken together, these studies indicate that previous research has generally examined digital infrastructure, FDI, and financial development separately. Consequently, limited evidence exists on how digital infrastructure quality and FDI jointly influence stock market capitalization, particularly through moderating mechanisms. This study addresses this gap by simultaneously examining the direct effects of digital infrastructure and FDI, as well as FDI's moderating role in the relationship between digital infrastructure and stock market capitalization.

Table 1 highlights several important patterns in the existing literature. While previous studies generally confirm that digitalization promotes financial development and that FDI contributes to capital market performance under favourable conditions, the two strands of literature remain largely disconnected. Moreover, limited evidence exists regarding whether digital infrastructure conditions the impact of FDI on stock market capitalization. This study addresses these gaps by integrating digital infrastructure quality, foreign direct investment, and stock market development within a unified empirical framework.

To motivate the empirical analysis, Figure 1 presents the cross-country association between digital infrastructure and stock market development based on average values over the 2012–2023 period. Although substantial heterogeneity exists across countries, a generally positive relationship is observed between broadband penetration and stock market capitalization. Countries with more developed digital infrastructure tend to exhibit larger stock markets relative to GDP than countries with weaker digital connectivity. While this descriptive evidence does not establish causality, it

provides an important indication that digital infrastructure may contribute to explaining differences in stock market development across countries.

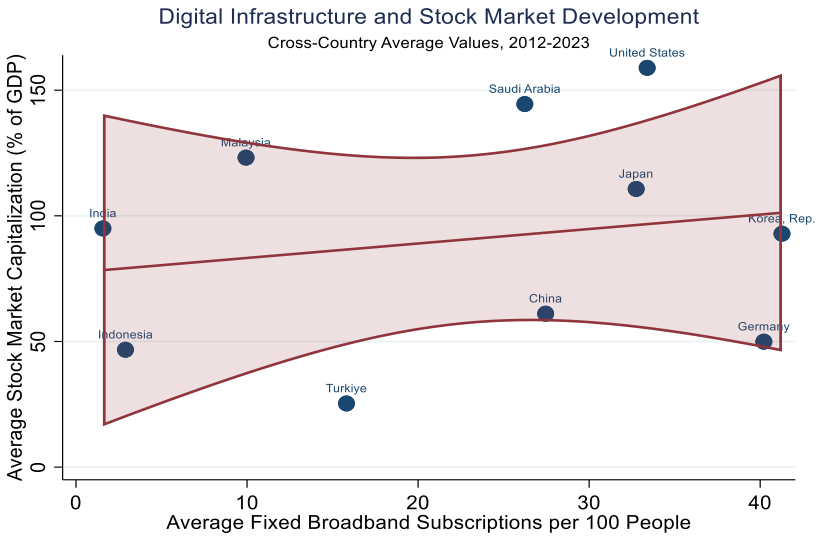

Figure 1. Digital Infrastructure and Stock Market Development Across Sample Countries (2012–2023 Average)

Against this background, the present study examines the role of digital infrastructure in stock market development using a panel of selected economies over the period 2012–2023. Unlike previous studies, the analysis incorporates multiple dimensions of digital infrastructure quality, including internet usage, fixed broadband subscriptions, and secure internet servers. The study also evaluates the role of foreign direct investment and investigates whether FDI moderates the relationship between digital infrastructure and stock market capitalization. By integrating Information Economics Theory (Akerlof, 1970), Financial Development Theory (Levine, 2004), and the FDI–financial development framework of (Alfaro et al., 2004), the study develops a comprehensive framework linking digitalization, foreign investment, and stock market development.

Building upon the preceding discussion, this study seeks to address several interrelated questions. Specifically, it investigates (i) whether digital infrastructure contributes to stock market development, (ii) whether foreign direct investment promotes stock market capitalization, (iii) whether foreign direct investment moderates the relationship between digital infrastructure and stock market development, and (iv) which dimension of digital infrastructure exerts the strongest influence on stock market capitalization. Addressing these questions contributes to a deeper understanding of how digital transformation and international capital flows jointly shape financial market development.

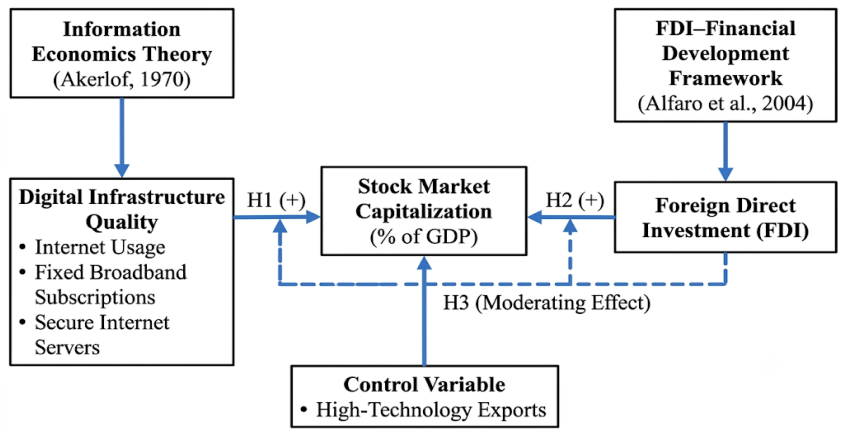

Figure 2. Theoretical Framework Linking Digital Infrastructure, Foreign Direct Investment, and Stock Market Capitalization

Figure 2 presents the conceptual framework of the study. Drawing on Information Economics Theory (Akerlof, 1970), Financial Development Theory (Levine, 2004), and the FDI–financial development framework (Alfaro et al., 2004), the framework proposes that digital infrastructure and FDI influence stock market development directly, while FDI may also condition the effect of digitalization. High-technology exports are included as a control variable because they capture broader technological and innovation capabilities that may affect financial market development independently of digital infrastructure (Fagerberg, 1988; Lall, 2000).

Building on the theoretical framework and empirical evidence discussed above, the expected relationships among digital infrastructure, foreign direct investment, and stock market capitalization can be derived from Information Economics Theory, Financial Development Theory, and the FDI–financial development framework.

Information Economics Theory posits that reducing information asymmetry improves market efficiency and investment decisions (Akerlof, 1970), while Financial Development Theory emphasizes the role of information processing and transaction efficiency in promoting financial market development (Levine, 2004). From these theoretical perspectives, digital infrastructure is expected to enhance stock market capitalization by lowering information costs, improving transparency, and broadening investor participation. This expectation is supported by previous studies showing that digitalization and ICT adoption promote financial and stock market development, while improvements in digital infrastructure enhance financial depth, efficiency, and market performance (Feng et al., 2025; Firmansyah et al., 2025; Igwilo & Sibindi, 2022; McClure et al., 2025; Nguyen et al., 2020; Shu, 2024). Likewise, the FDI–financial development framework suggests that foreign direct investment contributes to financial development through capital accumulation, technology transfer, managerial expertise, and international business linkages (Alfaro et al., 2004). These mechanisms are expected to stimulate stock market expansion by increasing investment opportunities and improving market performance, particularly under favorable financial and institutional conditions (Babarinde, 2025; Chettri & Bhattarai, 2023; Otuya, 2026; Özsoy, 2020). Furthermore, digital infrastructure may also shape the effectiveness of foreign direct investment by reducing information and transaction costs and enhancing a country's attractiveness to foreign investors, while FDI facilitates the transfer of technology, knowledge, and managerial capabilities that strengthen digital transformation (Mai, 2025; Rizaldi & Jayadi, 2022; Alfaro et al., 2004). Existing empirical evidence further indicates that the benefits of FDI depend on domestic structural conditions and that digitalization can reinforce the economic gains associated with foreign investment (Haruna et al., 2023; Santosa et al., 2025; Supriyanto et al., 2025). Taken together, these theoretical arguments and empirical findings suggest that digital infrastructure and foreign direct investment are likely to contribute positively to stock market capitalization, while the strength of the relationship between digital infrastructure and stock market development may vary according to the level of foreign direct investment.

Method

Research Design and Data Source

This study adopts a quantitative empirical framework based on panel data econometrics to investigate the relationship between digital infrastructure, high-technology exports, foreign direct investment (FDI), and stock market capitalization. The dependent variable, stock market capitalization, is measured as a percentage of GDP and serves as a comprehensive indicator of financial market development, capturing both market size and valuation dynamics. The explanatory variables are selected to reflect multiple dimensions of digitalization, structural transformation, and international capital flows.

The dataset consists of a balanced panel of 10 countries observed over the period 2012–2023, yielding a total of 120 country-year observations. The sample includes China, Germany, India, Indonesia, Japan, the Republic of Korea, Malaysia, Saudi Arabia, Türkiye, and the United States. These countries were selected purposively based on several considerations: (i) they represent both advanced and emerging economies, allowing the analysis to capture substantial variation in digital transformation, financial market development, and foreign investment dynamics, consistent

with internationally recognized market classifications (MSCI Inc., 2024); (ii) they account for a considerable share of global economic activity and stock market capitalization, making them particularly relevant for examining the determinants of stock market development; (iii) they exhibit significant heterogeneity in digital infrastructure quality, internet penetration, broadband connectivity, and technological development, which is essential for identifying cross-country relationships in panel-data analysis (International Telecommunication Union, 2024; World Bank, 2021); (iv) they encompass different stages of digital and financial development, thereby enhancing the external relevance of the findings across diverse economic environments (MSCI Inc., 2024); and (v) they provide consistent observations for all variables included in the study over the period 2012–2023, enabling the construction of a balanced panel and ensuring comparability across countries and time. Furthermore, the sample design is consistent with previous cross-country studies on digitalization and financial development that emphasize the importance of capturing variation in digital infrastructure, financial systems, and economic characteristics across countries (Li et al., 2024; Nguyen et al., 2020). Consequently, the sample selection was guided by theoretical relevance, economic significance, cross-country diversity, and data consistency rather than by sample size alone.

Model Specification

The empirical model is designed to examine both the direct effects of digital infrastructure and the conditional role of foreign direct investment (FDI) in stock market development. The specification includes internet usage, fixed broadband subscriptions, secure internet servers, high-technology exports, and FDI inflows, together with an interaction term between internet usage and FDI to capture potential moderating effects. Following the standard panel-data framework, the model incorporates country-specific effects to account for unobserved and time-invariant characteristics, such as institutional quality, regulatory environments, and structural features of financial systems. By controlling for this unobserved heterogeneity, the panel-data approach improves the reliability and consistency of the estimated relationships (Baltagi, 2021; Jeffrey M. Wooldridge, 2010).

Estimation Strategy

The estimation strategy begins with the application of both Fixed Effects (FE) and Random Effects (RE) estimators to address unobserved heterogeneity across countries. The FE model controls for all time-invariant country-specific factors by allowing each cross-sectional unit to have its own intercept, while the RE model treats these effects as random and uncorrelated with the explanatory variables. In cross-country panel analyses, the RE estimator is particularly useful because it exploits both within-country and between-country variation and allows the estimation of slowly changing variables that may be largely absorbed under FE specifications. (Bell & Jones, 2015) further argue that RE models can perform comparably to, and in some settings more efficiently than, FE models when the underlying assumptions are satisfied. The choice between these two approaches is determined using the Hausman specification test.

Final Model Specification

All variables are sourced from the World Development Indicators (WDI) database to ensure consistency and cross-country comparability. Logarithmic transformations are applied to high-technology exports and secure internet servers to reduce skewness and improve the reliability of the estimations.

The econometric specification of the model is presented as follows:

$$\text{Market\_cap}_{it} = \alpha + \beta_1 \text{Internet}_{it} + \beta_2 \text{Fixed\_broad}_{it} + \beta_3 \text{lnSecure}_{it} + \beta_4 \text{ln\_hightech}_{it} + \beta_5 \text{Foreign}_{it} + \beta_6 (\text{Internet} \times \text{Foreign})_{it} + u_i + \epsilon_{it} \quad (1)$$

Where $Market\_cap_{it}$ represents stock market capitalization in country i at time t. The variables $Internet_{it}$, $Fixed\_broad_{it}$, and $lnSecure_{it}$ capture different dimensions of digital infrastructure, while $ln\_hightech_{it}$ represents high-technology exports and $Foreign_{it}$ denotes foreign direct investment inflows. The interaction term $(Internet \times Foreign)_{it}$ is included to

examine whether the effect of foreign direct investment on stock market capitalization varies according to the level of digital connectivity.

The index $i$denotes the country and $t$denotes time. The term $u_i$represents unobserved country-specific effects, while ϵ_{it}denotes the idiosyncratic error term. This specification allows the model to control for unobserved heterogeneity across countries while simultaneously capturing both the direct and conditional effects of digital infrastructure and foreign direct investment within a unified panel-data framework.

Table 1. Variable Definition and Measurement

	Variables	Symbols	Units	Definition
1.	Stock Market Capitalization	Market_cap	% of GDP	Market value of listed domestic companies divided by GDP
2.	Internet Usage	Internet	% of population	Percentage of individuals using the internet
3.	Fixed Broadband	Fixed_broad	Subscriptions per 100 people	Number of fixed broadband subscriptions per 100 inhabitants
4.	Secure Internet Servers	lnSecure	Log (number)	Logarithm of secure internet servers (TLS/SSL certificates)
5.	High-Technology Exports	ln_hightech	Log (USD)	Logarithm of high-technology export values
6.	Foreign Direct Investment	Foreign	% of GDP	Net inflows of foreign direct investment relative to GDP
7.	Interaction Term	Int_FDI	—	Interaction between Internet usage and FDI

Source: World Development Indicators (WDI), World Bank

Result and Discussion

This section presents and discusses the empirical findings of the study. It begins with descriptive statistics and correlation analysis to provide an overview of the data characteristics and preliminary relationships among variables. This is followed by the econometric estimation results using Random Effects models, including both baseline and robust specifications. Finally, the section interprets the main findings in relation to existing theoretical and empirical literature, with particular attention to the role of digital infrastructure, technological development, and foreign direct investment in shaping stock market capitalization.

Table 2. Descriptive Statistics of Variables

Variable	Obs	Mean	Std. Dev.	Min	Max
Market cap	120	90.814	55.926	16.477	316.309
internet	120	71.021	24.853	11.100	100.000
fixed broad	120	22.875	15.004	1.152	46.568
lnSecure	120	12.180	2.672	7.070	17.957
ln hightech	120	24.355	2.273	18.881	27.565
foreign	120	1.639	0.997	0.009	5.416

Source Author's Calculation

Table 2 presents the descriptive statistics of the study variables. Stock market capitalization averages 90.814% of GDP, with substantial variation across countries, as reflected by a standard deviation of 55.926 and values ranging from 16.477 to 316.309. This indicates considerable differences in the level of stock market development within the sample. Internet usage records a relatively high mean of 71.021%, while fixed broadband subscriptions average 22.875 per 100 inhabitants, suggesting notable variation in digital infrastructure quality across countries. Foreign direct investment averages 1.639% of GDP and also exhibits considerable dispersion. Overall, the descriptive statistics reveal substantial cross-country heterogeneity in both digital and financial conditions, supporting the suitability of panel-data analysis.

Table 3 reports the country-level averages for the period 2012–2023 and reveals substantial heterogeneity across the sampled economies. Advanced economies such as Korea, Germany, Japan, and the United States exhibit high levels of digital development, with internet usage exceeding 84% and fixed broadband subscriptions ranging from 32 to 41 per 100 inhabitants. In contrast, internet usage in India averages only 23.5%, while broadband penetration remains below

3 subscriptions per 100 inhabitants in both India and Indonesia. Considerable variation is also observed in stock market capitalization, with the United States recording the highest average level at 158.9% of GDP, compared with only 25.3% in Türkiye. China reports the highest average level of high-technology exports, whereas Malaysia records the largest average FDI inflows. These differences highlight the diversity of the sample and support the suitability of the cross-country panel framework employed in this study.

Table 3. Descriptive Statistics by Country (Period Averages)

Country	internet	fixed_broad	lnSecure	ln_hightech	foreign	Market_cap
China	60.533	27.459	12.109	27.298	1.760	61.050
Germany	87.449	40.215	14.475	26.076	2.289	49.928
India	23.541	1.574	11.663	23.750	1.624	94.982
Indonesia	38.797	2.892	11.206	22.662	1.965	46.722
Japan	88.275	32.752	13.565	25.408	0.563	110.701
Korea, Rep.	92.921	41.276	11.381	25.808	0.796	92.892
Malaysia	80.275	9.941	10.843	25.159	3.104	123.169
Saudi Arabia	83.732	26.240	8.427	19.342	1.169	144.482
Turkiye	66.058	15.813	11.972	22.193	1.437	25.332
United States	84.280	33.393	16.158	25.853	1.681	158.883

Source Author's Calculation

Table 4. Pairwise correlations

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
(1) Market_cap	1.000					
(2) internet	0.366*	1.000				
	(0.000)					
(3) fixed_broad	0.236*	0.777*	1.000			
	(0.010)	(0.000)				
(4) lnSecure	0.115	0.408*	0.467*	1.000		
	(0.210)	(0.000)	(0.000)			
(5) ln_hightech	-0.059	0.209*	0.436*	0.530*	1.000	
	(0.521)	(0.022)	(0.000)	(0.000)		
(6) foreign	-0.023	-0.159	-0.246*	-0.037	0.107	1.000
	(0.800)	(0.084)	(0.007)	(0.689)	(0.246)	

*** p<0.01, ** p<0.05, * p<0.1

Source Author's Calculation

The pairwise correlation matrix provides preliminary insights into the relationships among the variables. Stock market capitalization is positively and statistically significantly correlated with internet usage (0.366) and fixed broadband subscriptions (0.236), indicating that higher levels of digital infrastructure are associated with greater financial market development. In contrast, the correlation between stock market capitalization and both high-technology exports and foreign direct investment is negative but statistically insignificant, suggesting the absence of a simple linear relationship at this stage. Among the explanatory variables, internet usage and fixed broadband subscriptions exhibit a strong positive correlation (0.777), reflecting their close association as complementary dimensions of digital development. Similarly, secure internet servers and high-technology exports are positively correlated with broadband infrastructure. Foreign direct investment shows weak correlations with most variables, except for a negative and statistically significant relationship with fixed broadband. Overall, while some moderate correlations are observed, particularly among digital variables, the results do not indicate severe multicollinearity that would invalidate the regression analysis.

Table 5. Hausman Specification Test Results

Test	**Statistic**	**p-value**	**Decision**
Hausman (1978) Test	8.641	0.195	Random Effects Preferred

Source Author's Calculation

The selection of the appropriate panel data model was guided by the Hausman (1978) specification test, which compares the Fixed Effects and Random Effects estimators. As shown in Table 5, the test generated a chi-square statistic of 8.641 with a p-value of 0.195. This result indicates that the null hypothesis cannot be rejected at the 5% significance level, supporting the use of the Random Effects model as the preferred specification. Accordingly, the subsequent analysis is based on Random Effects estimation. Furthermore, country-clustered robust standard errors are employed to ensure more reliable inference by addressing potential heteroskedasticity and serial dependence within countries over time.

Table 6. Regression Results (Random Effects – Baseline)

Market_cap	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
internet	1.219	0.467	2.61	0.009	0.304	2.134	***
fixed_broad	2.788	0.675	4.13	0.000	1.465	4.112	***
lnSecure	-0.066	2.892	-0.02	0.982	-5.735	5.603	
ln_hightech	-24.873	8.268	-3.01	0.003	-41.078	-8.668	***
foreign	34.810	15.295	2.28	0.023	4.832	64.789	**
int_fdi	-0.401	0.185	-2.17	0.030	-0.764	-0.039	**
Constant	535.159	197.217	2.71	0.007	148.621	921.698	***
Mean dependent var	90.814		SD dependent var	55.926			
Overall r-squared	0.096		Number of obs	120			
Chi-square	53.649		Prob > chi2	0.000			
R-squared within	0.360		R-squared between	0.062			

*** p<0.01, ** p<0.05, * p<0.1
Source Author's Calculation

Table 6 presents the baseline Random Effects estimation results for stock market capitalization. The findings indicate that internet usage has a positive and statistically significant effect ($\beta = 1.219$, $p = 0.009$), suggesting that higher levels of digital connectivity are associated with increased stock market development. Similarly, fixed broadband exhibits a strong positive and highly significant coefficient ($\beta = 2.788$, $p < 0.001$), highlighting the critical role of digital infrastructure in supporting financial market expansion. In contrast, secure internet servers (lnSecure) do not show a statistically significant effect ($\beta = -0.066$, $p = 0.982$), indicating that this variable does not contribute meaningfully to explaining variations in stock market capitalization within this specification.

High-technology exports are found to have a negative and statistically significant relationship with stock market capitalization ($\beta = -24.873$, $p = 0.003$), while foreign direct investment (FDI) shows a positive and significant effect ($\beta = 34.810$, $p = 0.023$). Furthermore, the interaction term between internet usage and FDI is negative and statistically significant ($\beta = -0.401$, $p = 0.030$), implying that the marginal effect of FDI decreases as internet penetration increases. The overall model is statistically significant, as indicated by the Chi-square statistic ($\chi^2 = 53.649$, $p < 0.01$), although the relatively low overall R-squared (0.096) suggests that additional factors may also influence stock market development beyond those included in the model.

Table 7. Robustness Analysis Using Random Effects with Country-Clustered Standard Errors

Market_cap	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
internet	1.219	0.752	1.62	0.105	-0.255	2.693	
fixed_broad	2.788	1.146	2.43	0.015	0.542	5.034	**
lnSecure	-0.066	3.11	-0.02	0.983	-6.161	6.029	
ln_hightech	-24.873	6.252	-3.98	0.000	-37.128	-12.619	***
foreign	34.81	18.748	1.86	0.063	-1.934	71.555	*
int_fdi	-0.0401	0.219	-1.83	0.067	-0.831	0.029	*
Constant	535.159	106.761	5.01	0.000	325.911	744.407	***
Mean dependent var	90.814		SD dependent var	55.926			
Overall r-squared	0.096		Number of obs	120			
Chi-square	44.550		Prob > chi2	0.000			
R-squared within	0.360		R-squared between	0.062			

*** p<0.01, ** p<0.05, * p<0.1
Source Author's Calculation

Table 7 reports the robustness analysis using Random Effects estimation with country-clustered standard errors. Following the recommendations of (Abadie et al., 2022), clustered standard errors provide a more conservative inference procedure by accounting for potential within-country dependence in the error terms. The results largely confirm the baseline findings, although the statistical significance of some variables becomes weaker under the more conservative inference procedure. Fixed broadband remains positively and significantly associated with stock market capitalization ($\beta = 2.788$, $p = 0.015$), indicating that digital infrastructure quality continues to support stock market development after controlling for within-country error dependence. In contrast, internet usage loses statistical significance ($\beta = 1.219$, $p = 0.105$), suggesting that its estimated effect is sensitive to the choice of standard error correction. Likewise, secure internet servers remain statistically insignificant ($\beta = -0.066$, $p = 0.983$), providing no evidence of a systematic relationship with stock market capitalization.

The negative and highly significant coefficient of high-technology exports remains stable across specifications ($\beta = -24.873$, $p < 0.001$), indicating a robust inverse association with stock market capitalization. Foreign direct investment (FDI) retains a positive coefficient and remains marginally significant at the 10 percent level ($\beta = 34.810$, $p = 0.063$), while the interaction term between internet usage and FDI remains negative and marginally significant ($\beta = -0.401$, $p = 0.067$). Following (Brambor et al., 2006), this interaction coefficient is not interpreted directly and is examined further through marginal effect analysis. Overall, the model remains jointly significant ($\chi^2 = 44.550$, $p < 0.01$), suggesting that the explanatory variables collectively contribute to explaining cross-country variation in stock market capitalization and that the main conclusions remain broadly robust to clustered standard error corrections.

Table 8. Marginal Effect of Internet Usage on Stock Market Capitalization at Different Levels of FDI

FDI Level	FDI Value	Marginal Effect of the Internet	Std. Error	p-value	95% Confidence Interval
Low FDI	0.64	0.784	0.666	0.239	[-0.521, 2.089]
Mean FDI	1.64	0.397	0.522	0.447	[-0.626, 1.419]
High FDI	2.64	0.010	0.439	0.983	[-0.852, 0.871]

Notes: Marginal effects are calculated following Brambor, Clark, and Golder (2006). Low, mean, and high FDI correspond to mean − 1 SD, mean, and mean + 1 SD, respectively.

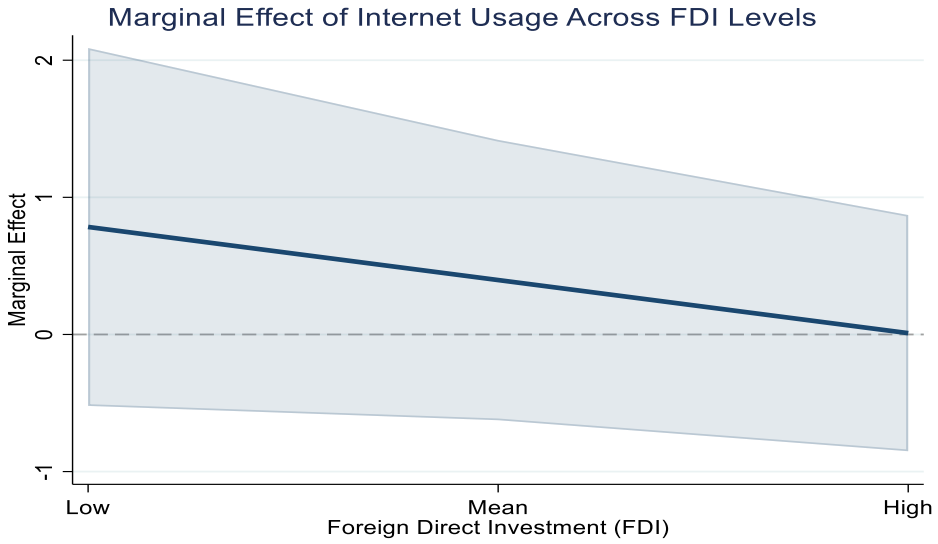

Figure 3. Marginal Effect of Internet Usage on Stock Market Capitalization Across Different Levels of FDI

Following the recommendations of (Brambor et al., 2006), the moderating role of FDI was further examined through marginal effect analysis. The results reported in Table 8 and illustrated in Figure 3 indicate that the marginal effect of internet usage on stock market capitalization declines as the level of FDI increases. Specifically, the estimated marginal effect decreases from 0.784 at low levels of FDI to 0.397 at the mean level of FDI and approaches zero (0.010) when FDI reaches

relatively high levels. This pattern suggests that the positive contribution of internet penetration to stock market development becomes weaker as FDI inflows increase.

However, the statistical evidence for this moderating relationship remains limited. The estimated marginal effects are not statistically significant at any of the evaluated FDI levels, as indicated by the corresponding p-values and the confidence intervals that consistently include zero. Therefore, while the results reveal a declining trend in the effect of internet usage across different levels of FDI, they do not provide sufficient evidence to conclude that FDI exerts a statistically robust moderating effect on the relationship between internet usage and stock market capitalization. These findings underscore the importance of interpreting interaction effects through marginal effect analysis rather than relying solely on the coefficient of the interaction term and suggest that the conditional influence of internet penetration on stock market development should be interpreted with caution.

The findings provide strong evidence that digital infrastructure plays an important role in stock market development across the sampled countries. Consistent with Information Economics Theory (Akerlof, 1970) and Financial Development Theory (Levine, 2004), the results indicate that improvements in internet usage and fixed broadband infrastructure contribute positively to stock market capitalization by reducing information asymmetries, lowering transaction costs, and facilitating broader investor participation in financial markets.

The positive effect of internet usage suggests that greater digital connectivity enhances the efficiency of information dissemination between firms, investors, and financial intermediaries. In modern capital markets, investment decisions depend heavily on the availability, speed, and quality of information. Higher internet penetration enables investors to access financial reports, market news, trading platforms, and corporate disclosures more efficiently, thereby reducing information acquisition costs and increasing market participation. This interpretation is consistent with (Akerlof, 1970) argument that reducing information asymmetry improves market efficiency. The finding also aligns with the empirical evidence of (Gheraia, 2024; Igwilo & Sibindi, 2022; Lee et al., 2017), who report that ICT diffusion contributes positively to stock market development and market capitalization. A plausible real-world example can be observed in countries such as Malaysia and Indonesia, where the rapid expansion of internet access has been accompanied by substantial growth in retail investor participation through digital trading applications. Similarly, (Feng et al., 2025) demonstrate that internet access increases household participation in financial markets by lowering informational and participation barriers. Recent studies by (Li et al., 2024; McClure et al., 2025) further support this mechanism by showing that digitalization improves stock price informativeness and reduces information acquisition costs, thereby strengthening market efficiency and investor confidence.

The results further reveal that fixed broadband infrastructure exerts an even strong, robust, and positive effect on stock market capitalization than general internet usage. This finding suggests that the quality of digital connectivity may be more important than simple digital access. Broadband infrastructure provides faster, more reliable, and more stable communication networks, which are essential for financial transactions, online trading systems, and real-time information processing. From an economic perspective, broadband enhances the operational efficiency of financial markets by improving connectivity between investors, financial institutions, and capital market platforms. The finding is consistent with (Frederic S Mishkin, 2022) who emphasizes the importance of information flows and transaction efficiency in financial market development. It also supports the empirical evidence provided by (HVIDE et al., 2024), who show that broadband expansion increases stock market participation and portfolio diversification among individual investors. Likewise, (He et al., 2024) find that digital infrastructure development significantly promotes financial depth and efficiency. A practical example can be observed in countries such as one of the study sample countries like South Korea, where advanced broadband infrastructure has supported highly integrated digital financial ecosystems and deep capital markets. The persistence of this result under clustered standard errors further indicates that broadband infrastructure represents one of the most robust determinants of stock market development within the sample.

In contrast, secure internet servers do not have a significant effect on stock market capitalization. This may be because secure servers primarily reflect the security quality of digital infrastructure rather than factors that directly expand investor participation or market activity. While cybersecurity enhances trust and transaction security, its impact is likely indirect and more closely related to financial stability and digital trust than to stock market size itself.

The negative and statistically significant coefficient of high-technology exports suggests that technological advancement does not necessarily translate into greater stock market development. While high-technology exports reflect innovation capacity, knowledge accumulation, and industrial sophistication (Fagerberg, 1988; Lall, 2000), these capabilities may be financed through channels other than equity markets. As argued by Franklin Allen and Douglas Gale (1999) and Levine (2002), technologically advanced economies often rely on bank-based financing, retained earnings, industrial networks, or government-supported funding mechanisms rather than stock market financing. Consequently, strong technological export performance may coexist with relatively smaller stock market capitalization. This interpretation is consistent with recent evidence showing that high-technology exports are primarily driven by broader structural factors such as human capital, innovation ecosystems, and institutional quality (Drapkin et al., 2024; Tebaldi, 2011; Zapata et al., 2024), which do not automatically foster capital market expansion.

The positive coefficient of foreign direct investment (FDI) supports the view that international capital inflows contribute to stock market development. FDI enhances financial development through capital accumulation, technology transfer, managerial spillovers, and improved business practices (Alfaro et al., 2004). Furthermore, foreign investors can strengthen corporate governance, increase demand for financial services, and promote integration between domestic and international capital markets. This finding is consistent with previous evidence showing that FDI contributes positively to capital market development (Babarinde, 2025; Chettri & Bhattarai, 2023; Haruna et al., 2023). However, the negative interaction between internet usage and FDI indicates that the relationship between digitalization and stock market development is conditional on the level of foreign investment. The marginal effect analysis shows that the positive effect of internet penetration declines as FDI increases, suggesting that in highly FDI-dependent economies, foreign capital inflows may already provide financial resources, technological access, and market connectivity, thereby reducing the additional contribution of internet expansion to stock market development. Nevertheless, since the marginal effects are statistically insignificant, this moderating effect should be interpreted as suggestive rather than conclusive.

A plausible explanation can be derived from the multinational enterprise literature. (Narula & Dunning, 2010) argue that multinational corporations often bring proprietary technologies, advanced information systems, managerial expertise, and international business networks into host countries. Consequently, when FDI levels are already high, foreign firms may internally provide many of the informational, technological, and organizational benefits that domestic digital infrastructure would otherwise generate. Under such circumstances, additional improvements in internet penetration may produce smaller incremental effects on stock market development because part of the digital advantage has already been supplied through multinational activity. This interpretation reflects a partial substitution effect rather than a genuinely negative relationship.

A real-world example can be observed in export-oriented emerging economies that host large multinational production networks. In these economies, foreign firms frequently operate sophisticated internal digital systems, international supply-chain platforms, and advanced information networks regardless of local internet penetration rates. As a result, increases in domestic internet usage may contribute less additional value to financial market development once substantial foreign investment is already present. This interpretation is also broadly consistent with recent studies emphasizing the conditional nature of FDI effects, including (Babarinde, 2025; Haruna et al., 2023; Mai, 2025), which show that the economic and financial benefits of FDI depend heavily on domestic structural conditions. Therefore, the interaction effect identified in this study appears to reflect diminishing returns rather than a contradiction of the broader digitalization-development nexus.

The findings support Information Economics Theory and Financial Development Theory by confirming that digital infrastructure is an important foundation for stock market development. Nevertheless, the results indicate that the effects of digitalization and FDI are conditional on broader structural and institutional factors, highlighting the interconnected nature of digital transformation, foreign investment, and financial market development.

Conclusion and Implications

This study provides evidence that the contribution of digitalization to stock market development depends more on the quality of digital infrastructure than on digital diffusion alone. The results demonstrate that fixed broadband infrastructure is the most consistent digital driver of stock market capitalization, maintaining a positive and statistically significant effect across both baseline and robustness specifications. By contrast, internet usage and secure internet servers do not exhibit robust effects after applying country-clustered standard errors, suggesting that basic digital access alone may be insufficient to deepen financial markets. The findings further reveal a positive role of foreign direct investment (FDI) in supporting stock market development, confirming that external capital can contribute to financial market expansion. However, although the interaction term between internet usage and FDI is negative and statistically significant in the baseline model, the marginal effect analysis indicates that the effect of internet usage gradually weakens as FDI increases and remains statistically insignificant across all evaluated FDI levels.

The findings suggest that policymakers should prioritize investments in high-quality digital infrastructure, particularly broadband networks, as a key component of financial market development strategies. Expanding broadband coverage and improving digital capacity can enhance information flows, reduce transaction costs, increase investor participation, and strengthen the efficiency of capital allocation within stock markets. At the same time, policymakers should not assume that digitalization alone will automatically deepen financial markets. Efforts to improve institutional quality, regulatory effectiveness, investor protection, and financial market sophistication remain essential for transforming digital progress into sustainable stock market growth. The positive contribution of FDI highlights the importance of maintaining an attractive investment environment; however, the absence of robust marginal effects suggests that policymakers should focus on maximizing the absorptive capacity of domestic financial systems rather than relying solely on foreign capital inflows. Furthermore, the negative association between high-technology exports and stock market capitalization indicates that innovation and export competitiveness should be accompanied by policies that strengthen domestic capital markets and facilitate the financing of innovative firms through equity-based instruments. Collectively, these measures can help ensure that digital transformation, technological advancement, and foreign investment are effectively integrated into the financial system and translated into long-term stock market development.

Acknowledgment

The corresponding author acknowledges Lecturer Heri Sudarsono for providing academic guidance and supervision during the preparation of this manuscript. The author also used AI-assisted language support tools solely for linguistic refinement and manuscript clarity of the manuscript. In addition, appreciation is extended to the author's parents for their prayers and support. The author also thanks all other contributors who played a role in this research.

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