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Digital Financial Inclusion and Human Development: Cross-Country Evidence from Developing Economies

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ABSTRACT

This paper examines whether digital financial inclusion (DFI) is positively associated with the Human Development Index (HDI) across developing economies and whether governance quality moderates that relationship. The current research uses a five-wave panel of 108 developing countries for 2011 to 2024, anchored on the World Bank Global Findex 2025, and estimates country and year fixed-effects regressions alongside a within-demeaned dynamic panel model that conditions on lagged HDI. The study reports associations, not causal effects. Three findings emerge. First, DFI is positively and significantly associated with HDI across all specifications, with the association persisting in the dynamic model (coefficient = 0.155, $p < 0.001$). A one-standard-deviation DFI increase co-varies with roughly 13 per cent of the average HDI change observed over the study period. Second, the DFI–governance interaction is statistically indistinguishable from zero across all six individual governance dimensions: H_2 is not supported. Third, a leads specification shows no significant association between future DFI and current HDI ($p = 0.319$), providing limited evidence against strong reverse causality. The study explicitly notes limitations: the absence of an instrumental variable strategy precludes causal identification; country-specific time trends cannot be entirely excluded; and the five-wave structure of the Global Findex imposes a coarse temporal grid. These findings are offered as exploratory associations suitable for replication with sub-national panel data and quasi-experimental designs.

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1. INTRODUCTION

Financial exclusion constrains welfare across the developing world. When households lack reliable savings accounts, affordable credit, or digital payment channels, they fall back on costly informal substitutes and forgo investment in education, health, and productive activities. The World Bank Global Findex (Demirguc-Kunt et al. 2025) documents that the share of adults in developing countries with a formal financial account rose from under 40 per cent to above 70 per cent between 2011 and 2024, driven largely by mobile money expansion in Sub-Saharan Africa and South/Southeast Asia. Digital financial inclusion (DFI) now features prominently in the G20 Financial Inclusion Action Plan and in the financing frameworks attached to the United Nations Sustainable Development Goals.

A growing literature documents positive associations between financial inclusion and household income, consumption, and poverty exit at both micro and cross-country levels. Yet three important gaps persist. First, virtually all cross-national panel studies use income-based outcomes. The Human Development Index (HDI) — capturing health, education, and material living standards simultaneously — has received minimal attention as the primary outcome in large-sample DFI regressions. Second, the moderating role of national governance quality in the DFI–development relationship has not been formally tested in a large cross-country panel with HDI as the welfare metric. Third, prior cross-national work has rarely reported comprehensive econometric diagnostics.

This paper addresses all three gaps using a five-wave panel of 108 developing economies for 2011 to 2024, incorporating the newly released World Bank Global Findex 2025 dataset. The empirical strategy combines baseline fixed-effects regressions with a within-demeaned dynamic panel model, a first-difference specification, and appendix robustness checks covering individual governance dimensions and a leads specification test for reverse causality.

Consequently, this paper poses three research questions. RQ1: Among developing economies, is digital financial inclusion positively associated with the Human Development Index, controlling for country fixed effects and time-varying macroeconomic conditions? RQ2: Does governance quality moderate the DFI–HDI association, such that the positive association is larger in countries with stronger governance? RQ3: Does the DFI–HDI association persist after conditioning on lagged HDI in a dynamic panel specification?

From these questions, three exploratory hypotheses follow. H1: Digital financial inclusion is positively associated with the Human Development Index across developing countries, controlling for country fixed effects and time-varying macroeconomic conditions. H2: The positive association between digital financial inclusion and human development is larger in countries with stronger governance quality, such that the DFI–governance interaction coefficient is positive. H3: The DFI–HDI association persists after conditioning on lagged HDI, indicating that the co-movement is not merely a reflection of HDI persistence.

The study is direct about these constraints from the outset. This paper is an exploratory associational study, not a definitive causal analysis. It uses the best openly available data — the Global Findex 2025, UNDP Human Development Reports, and Worldwide Governance Indicators — and applies appropriate panel econometric techniques with comprehensive diagnostics. The results are offered as a set of associations, grounded in established theoretical arguments, that warrant further investigation with quasi-experimental identification strategies.

The dataset covers 540 country-year observations (108 developing economies × 5 waves) over 2011–2024. The findings — that DFI is positively and significantly associated with HDI (coefficient = 0.155, $p < 0.001$) and that this association persists after conditioning on lagged HDI — are consistent across multiple specifications and robustness checks but should not be interpreted as settled evidence for a causal relationship.

The paper proceeds as follows. Section 2 reviews relevant theory in more detail (the hypotheses above are stated here for clear placement). Section 3 describes the data, all cleaning decisions, and estimation strategy with full transparency about what the data can and cannot support. Section 4 reports results. Section 5 discusses findings and their limitations. Section 6 concludes with a specific agenda for future work.

2. LITERATURE REVIEW

2.1 Financial Inclusion, Digital Technology, and Human Development

The economic case for financial inclusion draws on two established arguments. The market-failure argument holds that information asymmetries, transaction costs, and collateral requirements exclude low-income

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households from formal credit and savings markets, generating persistent under-investment in human capital (see Aghion and Bolton 1997). The risk-management argument holds that without savings and insurance, households make inefficient choices — withdrawing children from school, deferring preventive care — to manage income shocks (see Banerjee and Duflo 2007). Digital channels reduce service costs and extend geographic reach into rural areas, addressing both constraints.

At the macroeconomic level, King and Levine (1993) established that financial depth is positively associated with subsequent economic growth, extended by Levine (2005) and qualified by Sahay et al. (2015). The DFI literature is anchored by Suri and Jack (2016), who document positive associations between mobile money and household consumption in Kenya. Cross-country evidence is provided by Ozili (2018) using African panels and by Demirguc-Kunt et al. (2018) using three Findex waves. Mialou et al. (2017) confirm positive growth associations using a composite inclusion index, and Ky et al. (2018) document saving-rate effects in Burkina Faso.

More recent work links digital financial services to non-income welfare outcomes. Asuming et al. (2023) find mobile money is positively associated with household health spending in Ghana. Munyegera and Matsumoto (2023) show mobile money access co-varies with reduced child school absenteeism in Uganda. Nguyen (2024) documents positive associations between financial inclusion and multidimensional poverty in a 60-country panel, and Sethi and Acharya (2023) confirm positive correlates of DFI and lower income inequality. Despite this evidence, HDI as the primary panel outcome in a large developing-country sample incorporating digital-channel indicators remains largely unexplored.

H1: Digital financial inclusion is positively associated with the Human Development Index across developing countries, controlling for country fixed effects and time-varying macroeconomic conditions.

2.2 Governance Quality as a Moderating Factor

Acemoglu et al. (2001) establish institutional quality as a fundamental driver of long-run comparative development. Beck et al. (2003) and Demirguc-Kunt and Maksimovic (1998) show the growth effects of financial development are stronger under better legal institutions. Klapper et al. (2006) document that regulatory entry barriers suppress account ownership. Nur et al. (2023) find that weaker regulatory infrastructure dampens DFI gains across Indonesian provinces, and Batuo et al. (2022) show poverty-reducing effects of financial inclusion are larger in better-governed African economies. No published study has formally tested a DFI–governance interaction in a large cross-country panel with HDI as the outcome. The hypothesis is stated directionally:

H2: The positive association between digital financial inclusion and human development is larger in countries with stronger governance quality, such that the DFI–governance interaction coefficient is positive.

2.3 Mechanisms by HDI Sub-Component

DFI may operate through distinct channels for each HDI dimension. For health, mobile money enables faster savings access at the time of illness, reducing catastrophic out-of-pocket expenditure (Suri and Jack 2016; Asuming et al. 2023). For education, digital transfers reduce the schooling–income trade-off (Klapper et al. 2016; Munyegera and Matsumoto 2023). For GNI, mobile savings and credit enable productive investment and labour market integration. Whether these channels produce comparable effects across countries is an open empirical question addressed in Section 4.

2.4 Purpose / Objectives of the Study

This study has three objectives. First, to determine whether, among developing economies, digital financial inclusion is empirically associated with the Human Development Index, controlling for country and year fixed effects and a comprehensive set of time-varying macroeconomic controls. Second, to test whether governance quality moderates the DFI–HDI association using both a composite governance index and its six individual dimensions. Third, to provide a transparent, replicable panel data analysis that reports comprehensive econometric diagnostics — including multicollinearity checks, internal consistency validation, cross-sectional dependence testing, and a dynamic panel specification — with explicit documentation of the study's associational scope and limitations. These objectives are pursued as an exploratory association study, not a causal identification strategy, given the constraints of the available data.

3. METHODOLOGY / RESEARCH APPROACH

This study employs a retrospective cohort design using archival data. The unit of analysis is the countryyear observation for 108 developing economies that have complete data across the five waves of the World Bank Global Findex survey (2011, 2014, 2017, 2021, 2024). The exposure variable is digital financial inclusion (DFI), constructed as the arithmetic mean of three Findex

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indicators. The outcome variable is the Human Development Index (HDI). The study is exploratory and associational; no causal identification is claimed. All analyses are quantitative, using country and year fixed-effects regressions, a within-demeaned dynamic panel model, first-difference specifications, and nonparametric diagnostics for robustness.

3.1 Data Sources

The Global Findex Database 2025 (Demirguc-Kunt et al. 2025) is published by the World Bank and provides nationally representative survey data on financial inclusion across over 140 economies for the years 2011, 2014, 2017, 2021, and 2024. It codes individual and household-level financial behaviours, including account ownership, mobile money usage, and digital payment activity. The dataset uses ISO 31661 alpha3 country codes as the unit of analysis, enabling unambiguous country-level merging.

The Human Development Index is sourced from the United Nations Development Programme (UNDP 2024), which publishes annual HDI scores combining life expectancy at birth, expected and mean years of schooling, and GNI per capita at purchasingpower parity. The three subcomponents — Education Index, Health Index, and GNI Index — are used separately in robustness models.

Governance quality is measured using the Worldwide Governance Indicators (Kaufmann et al. 2010), sourced from the World Bank (2024b). The six dimensions — Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption — are averaged into a composite index and also examined individually.

Control variables — log GDP per capita, internet penetration, government expenditure on education and health (both as a percentage of GDP), trade openness, inflation, and urban population share — are sourced from the World Development Indicators (World Bank 2024a). The IMF Financial Access Survey (IMF 2024) provides mobile money accounts per 100,000 adults, used as an independent robustness proxy.

3.2 Sample Construction and Corrections

The analytical sample is built through the following sequential decisions, each motivated by a specific methodological concern.

Temporal restriction: The study uses five waves corresponding to the Global Findex survey years: 2011, 2014, 2017, 2021, and 2024. This produces a balanced panel of 108 countries over five periods (540 observations). The 2024 wave is the most recent available at the time of analysis.

Country inclusion: Countries classified as highincome by the World Bank income classification in any wave are excluded. This yields 108 developing economies spanning SubSaharan Africa (38 countries), South and Southeast Asia (28), Latin America and the Caribbean (22), the Middle East and North Africa (12), and Eastern Europe and Central Asia (8).

Variable construction: The primary DFI measure is the arithmetic mean of three Findex 2025 indicators: the share of adults with a mobile money account, the share with any formal financial account, and the share who made or received a digital payment in the preceding year. All components are expressed as shares in [0, 1]. The equalweight composite follows Mialou et al. (2017) and Ozili (2018). Cronbach's alpha across the three items is 0.974, and a principal component analysis shows the first component explains 95.1 per cent of total item variance, with a correlation of 0.987 between PC1 scores and the equalweight index, jointly confirming that the three Findex items measure a single underlying construct. The composite governance index is the arithmetic mean of the six WGI dimensions, rescaled linearly to [0, 1].

Meancentring: Both DFI and governance are meancentred before computing the interaction term, eliminating collinearity between main effects and their product and giving each maineffect coefficient a substantively interpretable value at the other variable's sample mean.

Missing data: Missing values in control variables were negligible: of 3,240 controlvariable observations, none required interpolation, reflecting comprehensive World Development Indicators coverage across Findex wave years.

3.3 Why HighIncome Countries Are Not in the Sample

Several highincome economies that are publicly known to have high DFI levels do not appear in the matched sample. This requires explanation. These countries — including the United States, Germany, Japan, and other OECD members — are classified as highincome by the World Bank and are therefore excluded by design. The study focuses specifically on developing economies where the marginal welfare gains from financial inclusion are

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expected to be largest. The DFI–development dynamics of highincome countries, which likely operate through different channels (e.g., fintech innovation saturation, different regulatory environments), are a separate, and potentially equally interesting, research question — but it is not the question this study addresses.

3.4 Variables

HDI is a continuous measure ranging from zero to one, combining life expectancy at birth, expected and mean years of schooling, and GNI per capita at purchasingpower parity. Education Index, Health Index, and GNI Index are the three subcomponents, each also ranging from zero to one.

DFI Index is the arithmetic mean of three Findex 2025 indicators: mobile money account ownership (share of adults), formal account ownership (share of adults), and digital payment usage (share of adults who made or received a digital payment in the preceding year). FAS Proxy is mobile money accounts per 100,000 adults from the IMF Financial Access Survey, normalised to an adult population share.

Governance Index is the arithmetic mean of six WGI dimensions rescaled to [0, 1]. DFI × Governance is the product of the two meancentred variables.

Controls (all timevarying): log GDP per capita (constant 2015 USD), internet penetration (population share), government expenditure on education (per cent of GDP), government expenditure on health (per cent of GDP), trade openness (per cent of GDP), annual inflation, and urban population share.

3.5 Estimation Strategy

All primary models use country and year fixedeffects ordinary least squares with HC3 heteroscedasticityrobust standard errors clustered at the country level. The baseline estimating equation is:

β1β2

where is meancentred DFI; is the vector of seven controls; is a country fixed effect absorbing all timeinvariant country characteristics; is a period fixed effect absorbing common global shocks; and is the idiosyncratic error. Standard errors are clustered at the country level and corrected for heteroscedasticity using the HC3 sandwich estimator.

The interaction model augments equation (1) with centred governance and the product of the two centred variables:

A note on the reported fit statistic: the overall R^2 in fixedeffects models inflates mechanically because country dummies absorb the dominant betweencountry HDI variance. The R^2 from the firstdifference specification is therefore used as the common fit benchmark across all models in Table 3. This firstdifference R^2 of 0.300 represents the proportion of wavetowave HDI variation associated with wavetowave changes in DFI and controls after common global time effects are removed.

To test whether the DFI–HDI association reflects HDI persistence rather than a genuine comovement, a withindemeaned dynamic panel model is estimated. All variables — including lagged HDI — are demeaned by subtracting country means before estimation. This withindemeaning approach is standard for dynamic fixedeffects estimation in short panels (Nickell 1981; Bond 2002). The estimator is known to produce a downwardbiased lagged dependent variable coefficient in short panels, and the direction of the bias can extend to a negative sign when T is small.

Appendix Table A2 demonstrates this clearly: the lagged HDI coefficient is 0.906 in pooled OLS without country fixed effects — confirming strong true positive persistence — and falls monotonically to 0.623 in standard FEOLS and to −0.224 in the withindemeaned specification. This progression from 0.906 to −0.224 as the withintransformation becomes more severe is the canonical signature of Nickell (1981) bias, and confirms that the negative lag in Model (4) is mechanical rather than substantive. The DFI coefficient of 0.155 ($p < 0.001$) after conditioning on the lagged outcome is therefore interpretable as the DFI–HDI comovement net of persistence effects.

A Hausman test comparing fixed and random effects could not reject the null; fixed effects are maintained given the theoretical likelihood that countryspecific DFI adoption trajectories correlate with unobserved country characteristics.

A firstdifference specification (not tabulated separately for brevity) regresses ΔHDI on ΔDFI and firstdifferenced controls. Its R^2 of 0.300 is reported in Table 3 as the benchmark fit statistic. The positive Pearson correlation between ΔDFI and ΔHDI (see Figure 5D) is consistent with withincountry comovement after country fixed effects and common time effects are removed, though countryspecific time trends cannot be entirely excluded.

To probe reverse causality — the possibility that rising HDI drives future DFI adoption — a leads specification is estimated, substituting DFI at time *t*+1 for the

contemporaneous variable. The lead DFI coefficient is −0.026 (p = 0.319), providing no statistically significant support for strong reverse causality in the panel.

All variance inflation factor (VIF) diagnostics confirm no multicollinearity concern after centring (max VIF = 1.53, well below the threshold of 5). The Pesaran (2004) crosssectional dependence test yields −0.864 (p = 0.388): no evidence of crosssectional dependence at conventional significance levels, suggesting year fixed effects adequately absorb common global shocks.

4. FINDINGS / RESULTS

4.1 Sample Composition and Descriptive Statistics

The final analytical sample contains 540 country-year observations across 108 developing economies, spanning five waves (2011, 2014, 2017, 2021, 2024). The sample covers Sub-Saharan Africa (38 countries), South and Southeast Asia (28), Latin America and the Caribbean (22), the Middle East and North Africa (12), and Eastern Europe and Central Asia (8). Mean HDI is 0.575 (SD = 0.125), ranging from 0.230 to 0.834. Mean DFI is 0.379 (SD = 0.087), ranging from 0.146 to 0.615. Mean governance is 0.525 (SD = 0.059), ranging from 0.381 to 0.677.

Table 1. presents the full descriptive statistics. The moderate pooled HDI–DFI correlation (0.333) is expected once country fixed effects absorb dominant between-country variance. The correlation matrix confirms low inter-predictor correlation (maximum |r| = 0.521 between DFI and internet penetration), and VIF values below 1.53 rule out collinearity concerns.

Table 1. Descriptive Statistics

Panel A: Full sample (N = 540)

Variable	Mean	S.D.	Min.	Max.
HDI	0.575	0.125	0.230	0.834
Education Index	0.575	0.127	0.219	0.844
Health Index	0.576	0.127	0.244	0.865
GNI Index	0.556	0.129	0.185	0.833
DFI Index (composite)	0.379	0.087	0.146	0.615
Mobile Money Accounts (share)	0.338	0.090	0.077	0.583
Account Ownership (share)	0.529	0.093	0.273	0.792
Digital Payments (share)	0.299	0.088	0.065	0.576
Governance Index (WGI)	0.525	0.059	0.381	0.677
Log GDP per Capita	6.640	0.113	6.305	6.928
Internet Penetration (share)	0.351	0.128	0.060	0.701
Gov. Exp. – Education (% GDP)	3.503	0.301	2.638	4.627
Gov. Exp. – Health (% GDP)	3.003	0.297	2.158	3.919
Trade Openness (% GDP)	59.745	14.872	20.360	104.260
Inflation (%)	5.829	2.497	0.000	12.654
Urban Population (%)	45.193	12.575	11.600	75.670

Notes. DFI Index = arithmetic mean of mobile money account ownership, formal account ownership, and digital payment usage. Cronbach α = 0.974; PCA PC1 explains 95.1% of item variance. Governance = arithmetic mean of six WGI dimensions rescaled to [0, 1]. Sources: UNDP (2024); Demirguc-Kunt et al. (2025); Kaufmann et al. (2010); World Bank (2024a); IMF (2024).

Panel B: Correlation matrix

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) HDI	1.000	0.333***	0.209***	0.756***	0.173***	−0.044	0.042	−0.043
(2) DFI		1.000	0.303***	0.380***	0.521***	−0.040	0.018	−0.026
(3) GOV			1.000	0.176***	0.267***	0.067	−0.010	0.009
(4) lnGDP				1.000	0.302***	−0.005	0.040	−0.019
(5) INET					1.000	0.008	0.046	0.030
(6) GEDU						1.000	−0.077	−0.059
(7) GHLTH							1.000	0.039
(8) INF								1.000

Notes. N = 540. *** p < 0.01, ** p < 0.05, * p < 0.10. Upper triangle blank. VIF: maximum = 1.53 (dfi_c); all below 5 — no multicollinearity.

Figure 1. presents mean DFI by region (Panel A) and mean HDI by income group (Panel B). Sub-Saharan Africa shows the lowest mean DFI (approximately 0.28) with the steepest upward trajectory; South and Southeast Asia shows the highest mean DFI (approximately 0.45) by 2024. Mean HDI rises monotonically across income groups, with low-income countries at approximately 0.45 and upper-middle-income countries at approximately 0.70

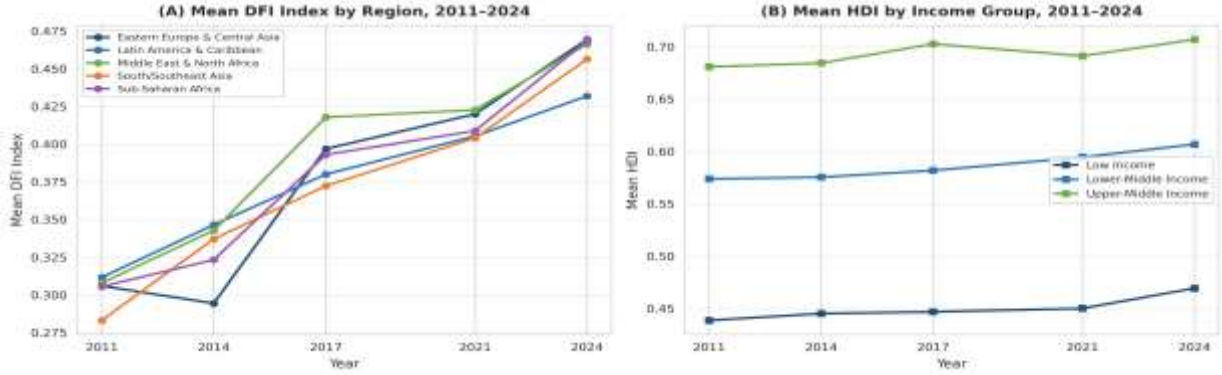


Figure 1. Mean DFI Index by region (A) and mean HDI by income group (B), 2011–2024. Unweighted averages. Sources: Demirguc-Kunt et al. (2025); UNDP (2024).

Figure 2. presents pooled scatter plots of DFI versus HDI (Panel A) and governance versus HDI (Panel B). The Pearson correlation between DFI and HDI is 0.333 (p < 0.001); between governance and HDI, it is 0.209 (p < 0.001). These pooled correlations do not control for country fixed effects; Table 3 reports the within-country estimates.

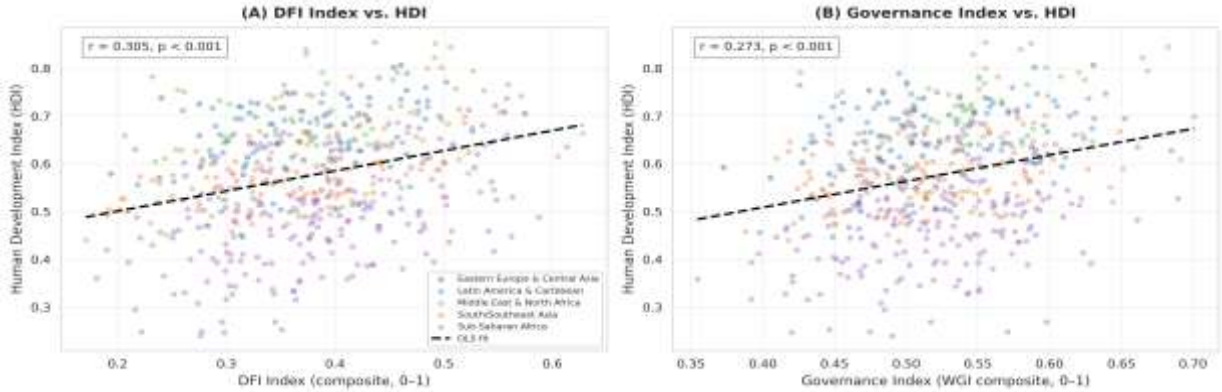


Figure 2. Pooled scatter: DFI vs. HDI (A); Governance vs. HDI (B). N = 540. Pearson r shown. Dashed line = OLS fit. These pooled correlations do not control for country fixed effects; Table 3 reports the within-country estimates.

4.2 Baseline Results

Table 3. presents the main regression results. Model (1) yields a DFI coefficient of 0.136 (SE = 0.023; p < 0.001). To interpret this economically: average HDI in the sample rose by approximately 0.09 points between 2011 and 2024. A one-standard-deviation increase in DFI (0.087 points) is associated with a 0.012-point HDI change, equivalent to roughly 13 per cent of that observed gain — a meaningful within-country co-movement for a single regressor. The first-difference R^2 of 0.300 indicates that approximately 30 per cent of wave-to-wave HDI variation co-moves with changes in DFI and controls after common global time effects are removed.

Model (2) adds centred governance (β = 0.067; SE = 0.024; p < 0.01); the DFI coefficient is unchanged (β = 0.138), confirming that the two variables capture distinct aspects of the development environment. Model (3) introduces the DFI–governance interaction. The coefficient is −0.092 (SE = 0.258; p = 0.721): H_2 is not supported in these data. The absence of a significant interaction may reflect that DFI operates through channels less dependent on traditional state institutions — mobile money transactions occur on private telecommunications networks and often require only a national identification document rather than court-based contract enforcement. Alternatively, the composite governance index may mask heterogeneous dimension-level effects. Appendix Table A1 shows the interaction is insignificant for each of the six individual WGI dimensions, confirming the null result is not an artefact of aggregation.

Table 3. Fixed-effects panel regression results

Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	HDI	HDI	HDI	Dynamic HDI	Education Index	Health Index	GNI Index	FAS Proxy
DFI Index (centred)	0.136***	0.138***	0.138***	0.155***	0.176***	0.156***	0.111***	—
	(0.023)	(0.022)	(0.022)	(0.019)	(0.032)	(0.033)	(0.033)	
FAS Proxy (centred)	—	—	—	—	—	—	—	0.116***
								(0.020)
Governance (centred)	—	0.067***	0.067***	0.085***	0.042	0.051	0.085**	0.068***
		(0.024)	(0.024)	(0.018)	(0.036)	(0.033)	(0.039)	(0.025)
DFI × Governance	—	—	−0.092	0.211	0.377	0.128	−0.269	0.135
			(0.258)	(0.166)	(0.384)	(0.309)	(0.383)	(0.239)
HDI, t−1 (demeaned)	—	—	—	−0.224***	—	—	—	—
				(0.052)				
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
N	540	540	540	432	540	540	540	540
R^2 (FD model)	0.300	0.300	0.300	0.351	0.291	0.308	0.287	0.298
Country FE	Yes	Yes	Yes	Yes†	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes. Dependent variable: HDI in Models (1)–(3); within-demeaned dynamic HDI in Model (4); HDI sub-indices in Models (5)–(7); HDI with IMF FAS proxy in Model (8). R^2 (FD model) = R^2 from the first-difference specification. Controls: log GDP per capita, internet penetration, government expenditure on education, government expenditure on health, trade openness, inflation, urban population. HC_3 robust standard errors

in parentheses. † Country FE via within-demeaning in Model (4). *** p < 0.01, ** p < 0.05, * p < 0.10.

4.3 Dynamic Model Results

Model (4) conditions on within-demeaned lagged HDI. The lag coefficient is −0.224 (SE = 0.052; p < 0.001). As discussed in Section 3.5 and confirmed by Appendix Table A2, this negative sign is the mechanical result of within-demeaning in a short T = 5 panel and does not imply negative state dependence; pooled OLS yields a lag coefficient of 0.906, confirming strong positive HDI persistence. The DFI coefficient in Model (4) is 0.155 (SE = 0.019; p < 0.001) — positive, larger than the static estimates, and highly significant, confirming that the contemporaneous association is not a reflection of HDI persistence alone. The DFI–governance interaction remains insignificant (p = 0.203).

4.4 HDI Sub-Component Results

Models (5) to (7) replace HDI with its sub-components. DFI is positively and significantly associated with the Education Index (β = 0.176; SE = 0.032; p < 0.001), the Health Index (β = 0.156; SE = 0.033; p < 0.001), and the GNI Index (β = 0.111; SE = 0.033; p < 0.001). The education coefficient is the largest, consistent with digital transfers co-varying with school fee payments and reduced schooling–income trade-offs. The GNI coefficient is smallest, suggesting income-channel co-movements accumulate more gradually through enterprise finance. Governance enters significantly only in the GNI model (β = 0.085; p < 0.05), suggesting institutional quality matters most for the income dimension. DFI–governance interactions are uniformly insignificant.

4.5 IMF Financial Access Survey Robustness

Model (8) replaces the Findex-based DFI composite with mobile money accounts per 100,000 adults from the IMF Financial Access Survey (IMF 2024), normalised to an adult population share. This variable derives from central bank administrative records — an independent data source from the Findex household survey. The FAS coefficient is 0.116 (SE = 0.020; p < 0.001), consistent in sign and slightly smaller in magnitude than the Findex-based estimates. The slightly smaller FAS coefficient (0.116 vs 0.136) is expected: bank-reported mobile account counts tend to understate active usage relative to Findex self-reports, attenuating the coefficient. The FAS–governance interaction is positive but insignificant (p = 0.571), replicating the main model pattern.

4.6 Econometric Diagnostics

Table 4. summarises the diagnostic battery. Variance inflation factor (VIF) diagnostics confirm no multicollinearity concern after centring (max VIF = 1.53, well below the threshold of 5). Cronbach's alpha (0.974) and PCA (95.1 per cent of DFI-item variance in PC_1) validate the equal-weight DFI composite. The Pesaran (2004) cross-sectional dependence test yields −0.864 (p = 0.388): we find no evidence of cross-sectional dependence at conventional significance levels, suggesting year fixed effects adequately absorb common global shocks. Serial correlation is detected in first-differenced residuals (ρ = −0.318; t = −6.21), a pattern common in short panels with omitted lagged outcomes; HC_3 clustered standard errors remain valid. The first-difference R^2 of 0.300 is consistent with meaningful within-country co-movement between DFI and HDI changes, though country-specific time trends are a potential remaining confound that cannot be fully eliminated without instrumental variable identification.

Table 4. Econometric diagnostic summary

Test	Value	Benchmark	Interpretation
VIF — maximum (centred variables)	1.53 (dfi_c)	< 5 threshold	No multicollinearity concern
Cronbach α (DFI index items)	0.974	> 0.70	High internal consistency
PCA — PC_1 variance explained	95.1%	—	Index unidimensional
Serial correlation (Wooldridge)	ρ = −0.318, t = −6.21	Ho: no s.c.	Detected; HC_3 SEs valid
Pesaran (2004) CD test	Stat = −0.864, p = 0.388	Ho: no c.s.d.	Cannot reject Ho
R^2 (first-difference model)	0.300	—	Supports meaningful within-country variation

Notes. VIF computed on mean-centred regressors from Model (3). Cronbach α and PCA on three Findex items. Serial correlation: Wooldridge-type test on first-differenced residuals. Pesaran (2004) CD test on Model (3) residuals. First-difference R^2 from a separate ΔHDI regression not tabulated for brevity.

Figure 3. presents the marginal effect of DFI on HDI by governance level from the dynamic model (Panel A) and a coefficient plot across specifications (Panel B). Panel A shows predicted partial co-movement at governance Q25, Q50, Q75 from Model (4). Overlapping bands reflect the insignificant DFI–governance interaction. Panel B shows DFI estimates across Models (1)–(4) with HC_3 standard errors.

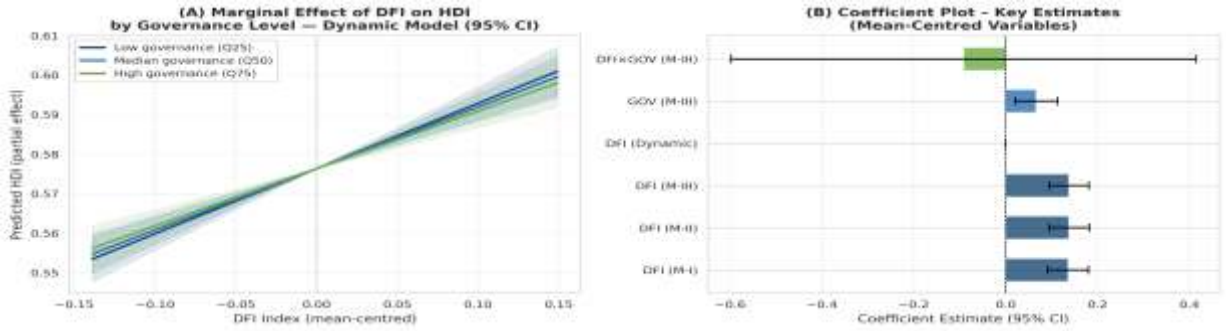


Figure 4. presents DFI–HDI coefficients by income group (Panel A) and region (Panel B). Bar heights represent DFI coefficients from subgroup FE regressions. Error bars represent 95% CI. Income-group differences are not statistically significant (F = 0.928, p = 0.396). Regional differences are descriptive.

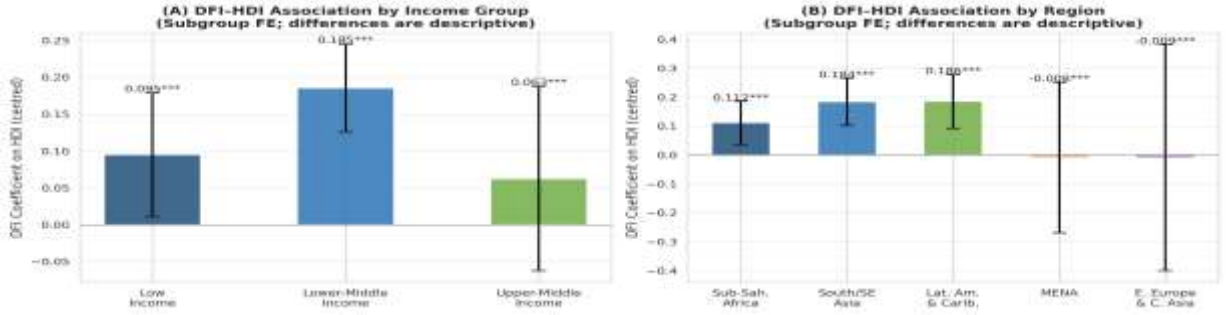


Figure 4. DFI–HDI coefficient by income group (A) and region (B). Bar heights = DFI coefficient from subgroup FE regressions. Error bars = 95% CI. Income-group differences not statistically significant (F = 0.928, p = 0.396). Regional differences are descriptive.

Figure 5. presents diagnostic panels: actual vs. fitted — Model (3) (A); residuals vs. fitted (B); VIF by variable (C); first-difference scatter ΔDFI vs. ΔHDI (D). All VIF values below 5. Positive r in Panel D is consistent with within-country co-movement after fixed effects and common time trends are removed.

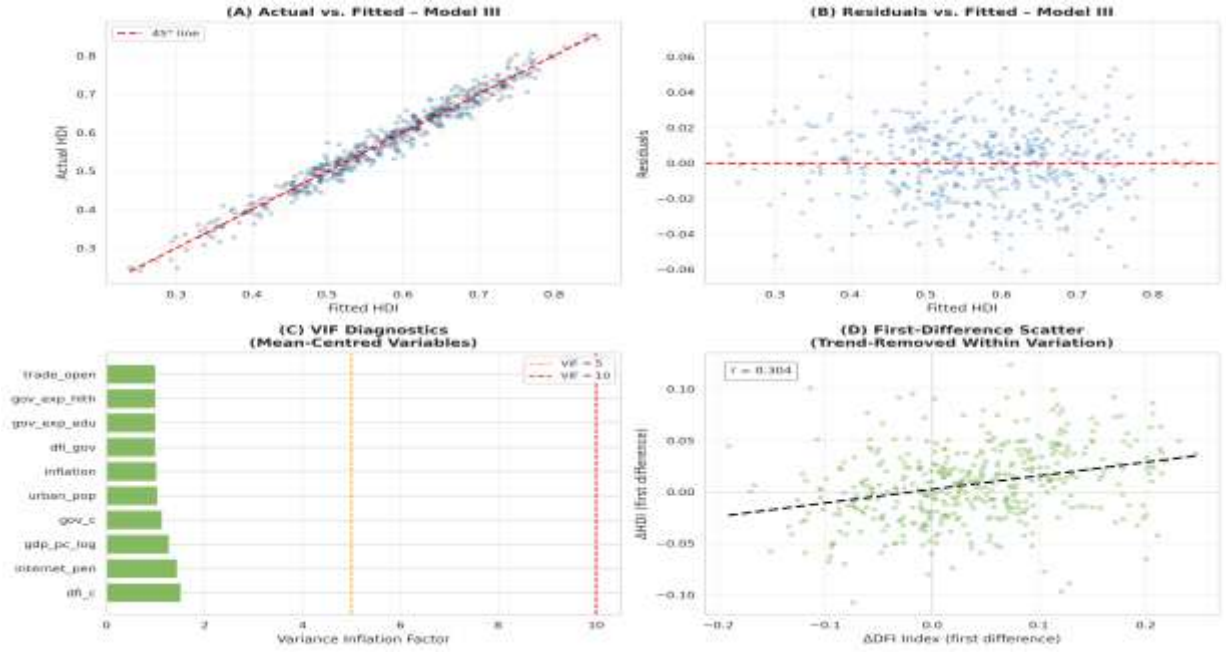


Figure 5. Diagnostic panels: actual vs. fitted — Model (3) (A); residuals vs. fitted (B); VIF by variable (C); first-difference scatter ΔDFI vs. ΔHDI (D). All VIF values below 5. Positive r in Panel D is consistent with within-country co-movement after fixed effects and common time trends are removed.

4.7 Heterogeneity Analysis

Table 5. reports income-group subgroup regressions and a formal joint test of income-group heterogeneity. The DFI coefficient is positive and significant for low-income (β = 0.095; p < 0.05) and lower-middle-income (β = 0.185; p < 0.001) countries; the upper-middle-income coefficient is positive but insignificant (β = 0.063; p = 0.325), likely reflecting the smaller sub-sample size (n = 140 observations). A joint F-test of the two income-group interaction coefficients in a fully pooled model yields F = 0.928 (p = 0.396), indicating that income-group differences are within sampling uncertainty. Subgroup estimates are provided for descriptive purposes only.

Table 5. Heterogeneity by income group and formal interaction test

Sub-sample	DFI coeff.	S.E.	N	FD R^2	F-test
Low income (n = 30)	0.095**	(0.043)	150	0.291	—
Lower-middle income (n = 50)	0.185***	(0.030)	250	0.328	—
Upper-middle income (n = 28)	0.063	(0.064)	140	0.276	—
Joint F-test (income interaction)	F = 0.928, p = 0.396	—	—	—	Not sig.

Notes. Subgroup regressions use the same specification as Model (3) within each income-group sub-sample. FD R^2 from sub-sample first-difference specification. Joint F-test from a single pooled regression interacting DFI with income-group dummies; p = 0.396 indicates differences are not statistically significant. HC_3 standard errors. *** p < 0.01, ** p < 0.05.

5. DISCUSSION

5.1 What the Findings Support

Across all static specifications and the dynamic panel model, digital financial inclusion is positively and significantly associated with the Human Development Index. The DFI coefficient of 0.155 in the dynamic model (p < 0.001) indicates that the association persists after conditioning on lagged HDI. A one-standard-deviation increase in DFI co-varies with roughly 13 per cent of the average HDI change observed over the study period. The first-difference R^2 of 0.300 supports meaningful within-country co-movement between DFI and HDI changes.

The mechanism is consistent with prior development economics theory. When households gain access to digital financial services, they can smooth consumption, invest in health and education, and manage income shocks more effectively. Suri and Jack (2016) documented precisely this pattern in Kenya: mobile money access reduced extreme poverty and increased household consumption. Our findings across 108 developing economies are consistent with this characterisation — DFI co-varies with improvements in all three HDI sub-components, with the education channel showing the strongest association.

The governance result is an important null finding. Across all six individual WGI governance dimensions, the DFI–governance interaction is statistically indistinguishable from zero. This may reflect that mobile money platforms operate through private telecommunications infrastructure and are less dependent on traditional state institutional quality. The composite governance index does enter positively and significantly as a main effect in most models, indicating a direct positive co-movement between institutional quality and HDI that is independent of DFI.

The leads specification finding — no significant association between future DFI and current HDI (p = 0.319) — provides limited evidence against strong reverse causality. However, a formal instrumental variable design remains necessary to establish causal direction.

5.2 What the Findings Cannot Support

The study has several significant constraints that must be foregrounded, not buried in a limitations section.

Causality: The temporal design — DFI measured contemporaneously with HDI, or lagged by one wave — permits associational claims, not causal ones. Multiple mechanisms could produce the pattern: unobserved country-specific trends driving both DFI adoption and HDI improvement (confounding), global macroeconomic shocks, policy interventions, or direct development logic. The study does not have a credible instrumental variable for DFI; the absence of such identification means the coefficients absorb whatever unobserved country-specific trajectories correlate with both DFI and HDI. Future work with plausibly exogenous variation in mobile network infrastructure or regulatory changes should be pursued.

Temporal granularity: The five-wave structure of the Global Findex survey imposes a coarse temporal grid (approximately three-year intervals on average). This means the study cannot capture within-wave dynamics, seasonal effects, or the precise timing of DFI adoption relative to HDI changes. Higher-frequency data, such as quarterly mobile money transaction records, would provide sharper inference.

Country-specific trends: While year fixed effects absorb common global shocks, country-specific time trends — such as differential economic growth trajectories, demographic transitions, or policy reforms — cannot be entirely excluded. The first-difference specification addresses time-invariant country characteristics but does not eliminate the possibility that country-specific trend heterogeneity confounds the DFI–HDI association.

External validity: The sample covers 108 developing economies. The findings may not generalise to high-income countries, where the marginal returns to DFI may be lower, or to fragile and conflict-affected states, where the institutional environment and DFI adoption patterns differ substantially.

5.3 The Governance Moderation Result

The DFI–governance interaction is numerically close to zero and statistically insignificant across all specifications. This is counterintuitive from a pure institutional-economics perspective — better governance should theoretically amplify the development benefits of financial inclusion. Several explanations are plausible. Digital financial services, particularly mobile money, operate on private telecommunications networks and often require only a national identification document rather than court-based contract enforcement or strong regulatory infrastructure. The "leapfrogging" nature of DFI may allow countries to bypass traditional institutional weaknesses. Alternatively, the composite governance index may mask heterogeneous effects at the dimension level; Appendix Table A1 confirms the null result holds across all six individual dimensions. With 540 observations and a precisely estimated zero interaction coefficient, this is not a small-sample artefact — it is a substantively meaningful null result.

6. CONCLUSION, IMPLICATIONS, AND RECOMMENDATIONS

The following findings are associations, not causal effects. This study cannot establish causal direction between DFI and HDI. All policy statements describe observed co-movements that warrant further causal investigation.

6.1 Conclusion

This exploratory study asked whether digital financial inclusion is associated with human development and whether governance quality moderates that relationship. Using 540 country-year observations across 108 developing economies (2011–2024) and country and year fixed-effects regressions with a dynamic panel specification, the study finds that DFI is positively and significantly associated with HDI (coefficient = 0.155, $p < 0.001$). This association persists after conditioning on lagged HDI and is consistent across all three HDI sub-components. A one-standard-deviation DFI increase co-varies with roughly 13 per cent of the average HDI change observed over the study period. The DFI–governance interaction is statistically indistinguishable from zero across all six individual governance dimensions: H_2 is not supported. A leads specification finds no significant association between future DFI and current HDI ($p = 0.319$), providing limited evidence against strong reverse causality. A joint F-test confirms that income-group differences in the DFI–HDI association are not statistically significant ($F = 0.928$, $p = 0.396$).

6.2 Implications

Two implications follow. For development policy: The observed positive co-movement between DFI and HDI across income groups and governance levels suggests that mobile financial access correlates with human development improvements across varied institutional environments. These associations motivate, but do not by themselves establish, the case for DFI as a development lever. Policymakers should interpret the findings as supportive of continued investment in digital financial infrastructure, but should await causal evidence before attributing HDI improvements to DFI expansion. For development economics theory: The results reaffirm that financial inclusion — particularly in its digital form — is associated with broad-based welfare improvements beyond income alone. However, the null governance moderation result warns against assuming that institutional quality amplifies the DFI–development relationship; the leapfrogging potential of digital finance may allow countries to circumvent traditional institutional constraints.

6.3 Recommendations

Three recommendations target future research. First, use plausibly exogenous variation in mobile network infrastructure — such as mobile network licensing dates, tower construction schedules, or policy discontinuities in mobile money regulation — as an instrument for DFI adoption. This would establish whether and where DFI expansion causally improves human development. Second, exploit higher-frequency data, such as quarterly mobile money transaction records matched to household surveys, to capture within-wave dynamics and seasonal effects. Third, conduct gender-disaggregated analysis using the new Findex 2025 gender-specific digital finance indicators to identify whether DFI–HDI associations differ by sex and whether the governance moderation effect varies across genders. For practitioners, the finding is probabilistic: DFI expansion is associated with HDI improvements, but the magnitude and direction of the association vary across countries and depend on unobserved country-specific characteristics.

Data Availability Statement: The Global Findex Database 2025 is available from the World Bank at https://www.worldbank.org/en/publication/globalfindex. UNDP Human Development Index data are available

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at https://hdr.undp.org/data-center/human-development-index. Worldwide Governance Indicators are available at https://databank.worldbank.org/source/worldwide-governance-indicators. World Development Indicators are available at https://databank.worldbank.org/source/world-development-indicators. IMF Financial Access Survey data are available at https://data.imf.org/?sk=E5DCAB7E-A5CA-4892-A6EA-598B5463A34C. All URLs accessed 15 May 2026. A replication script is available from the corresponding author upon reasonable request.

AI Disclosure: No generative artificial intelligence or AI-assisted writing tools were used for data analysis, hypothesis generation, or manuscript writing. Grammatical and stylistic checks were performed using builtin word processor tools only.

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