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Article

Digital Amplifiers: Internet Penetration, Islamic Banking, and the Sustainable Development Goals

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Abstract: This paper asks whether digital infrastructure and Islamic banking are complements or substitutes in advancing the Sustainable Development Goals (SDGs). Using an annual panel of up to 57 countries over 2007-2024 (N = 846-1,026), the study estimates the association between Islamic banking depth (IBA, percentage of total banking assets), internet penetration, and their interaction on five SDG scores, using Method of Moments Quantile Regression (MMQR) as the primary estimator with Driscoll-Kraay, FGLS and PCSE as robustness checks. Three findings emerge. First, Islamic banking depth is positively and significantly associated with all five SDGs, most strongly with SDG9 (industry, innovation and infrastructure; median coefficient = 1.196, $p < 0.01$). Second, once internet penetration and an IBA*internet interaction are introduced, the interaction is positive and significant for SDG9 ($b = 0.001$, $p < 0.01$): the marginal association between Islamic banking depth and SDG9 is roughly 50 percent larger in a fully internet-penetrated economy than in one with no internet access. Third, this amplification is concentrated in the lower and middle quantiles of the SDG9 distribution and is goal-specific, appearing for SDG8 and SDG9 but not for SDG1, SDG7 or SDG10. The findings are directly relevant to Uzbekistan, which combines internet penetration near 90 percent with an Islamic banking sector that became legally permissible only in June 2026.

Keywords: Islamic banking, internet penetration, sustainable development goals, SDG9, quantile regression, Uzbekistan

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1. Introduction

The 2030 Agenda for Sustainable Development is, at its core, a financing problem: the annual investment gap facing developing economies is estimated at roughly US$4 trillion. Two forces are frequently proposed, separately, as partial remedies. The first is Islamic finance, whose asset-backing requirement and prohibition of riba and gharar tie funding to tangible, productive activity, and whose global assets are projected to reach approximately US$6 trillion in 2024. The second is digital infrastructure, which lowers the transaction cost of intermediation and has expanded account ownership, credit access and payments usage at a pace branch-based banking cannot match. Both literatures are well developed in isolation. What remains largely unexamined is whether these two channels reinforce or undercut one another when they operate in the same economy at the same time.[1]

This question is not merely academic. A growing number of countries are simultaneously investing in digital public infrastructure and building Islamic banking

sectors from a low base, Uzbekistan foremost among them. If digital infrastructure amplifies the SDG contribution of Islamic banking, sequencing the two reforms together is a genuine policy complementarity. If digital infrastructure principally advantages conventional banks, which typically hold larger technology budgets and longer digital-channel track records, an aggressive digitalization agenda could inadvertently crowd out the Islamic banking sector even as it expands financial access overall.[2]

The empirical strategy proceeds in two steps on an annual panel of up to 57 countries over 2007–2024 (N = 846–1,026). First, the paper establishes a baseline association between Islamic banking asset share (IBA) and five SDG scores using Method of Moments Quantile Regression (MMQR; Machado and Santos Silva), which recovers the full conditional distribution rather than a single conditional-mean estimate. Second, it augments the specification with internet penetration and an IBA*internet interaction term, testing whether the marginal SDG contribution of Islamic banking depth varies with digital infrastructure development.[3]

Three findings emerge. Islamic banking depth is positively and significantly associated with all five SDGs, most strongly with SDG9. Internet penetration amplifies rather than substitutes for this association: the interaction term is positive and significant for SDG9, implying that a given increase in Islamic banking depth is associated with roughly 50 percent more SDG9 progress in a fully digitalized economy. This amplifier is strongest in the lower and middle quantiles of the SDG9 distribution and attenuates to insignificance at the top, and it is goal-specific, appearing for SDG8 and SDG9 but not for SDG1, SDG7 or SDG10.[4]

These findings speak directly to Uzbekistan, which combines internet penetration of 89–94 percent with a below-median SDG9 score, and whose Law on Islamic Banking entered into legal force on 28 June 2026. The remainder of the paper is organized as follows. Section 2 reviews the literature and develops the hypotheses; Section 3 describes data and methodology; Section 4 reports results; Sections 5 and 6 discuss the findings and their policy implications for Uzbekistan; Section 7 concludes.

1.1. Islamic Finance and the Sustainable Development Goals

The theoretical case for a positive association between Islamic finance and sustainable development rests on the maqasid al-Sharia, which encompass the preservation of wealth, life, intellect, posterity and faith, and on the structural features of Islamic contracts—asset-backing, risk-sharing, and the prohibition of riba and gharar—that tie financing to tangible, productive activity rather than to purely financial speculation. Empirically, panel evidence broadly supports a positive growth and development effect. Yusof and Bahlous link Islamic banking to growth and macroeconomic efficiency across GCC and East Asian economies; Butt, Sadaqat and Shear and Kismawadi document positive growth associations in developing-country panels; Aliyu et al. provide a systematic review of Islamic banking sustainability and explicitly call for cross-country empirical work linking Islamic banking to development outcomes. Ameziane documents growth effects of Islamic financial inclusion across OIC economies, and Novreska and Arundina report poverty, inequality and human-development effects in Indonesia.[5]

1.2. Digital Finance, Internet Penetration and Development

A separate and largely parallel literature establishes that digital infrastructure is itself a powerful driver of financial inclusion and development outcomes. Demirguc-Kunt et al. document that mobile and internet-based financial services have been the single largest driver of account ownership growth in developing economies since 2011. Gomber, Koch and Siering show that digital channels reduce the fixed costs of intermediation that historically excluded low-income and rural populations from formal finance. Ozili argues that digital finance is associated with improved financial inclusion

and, under certain conditions, financial stability. Banna and Alam and Alnasser Mohammed et al. extend this to bank risk-taking and poverty alleviation respectively.

1.3. The Digital Amplifier Hypothesis

Two competing mechanisms link digital infrastructure to the developmental contribution of Islamic banking. The substitution mechanism holds that digital infrastructure is a non-exclusive public good: it lowers the cost of conventional digital banking at least as much as that of Islamic digital banking, and where conventional banks have deeper technology budgets and first-mover advantage, rising internet penetration should advantage conventional banking disproportionately, competing away Islamic banking market share and, with it, its distinct developmental contribution.[6]

The complementarity mechanism holds that, market-share effects aside, digital infrastructure changes what a given unit of Islamic banking depth can accomplish. Sukuk issuance, trade and supply-chain financing, and asset-backed project finance—the instruments through which Islamic banking is theorized to support SDG9—depend on digital rails for investor onboarding, documentation, payments and secondary-market liquidity in ways that materially lower the transaction cost of mobilizing capital for real-sector projects. The two mechanisms are not mutually exclusive: digital infrastructure can simultaneously shrink the Islamic banking sector market share (an extensive-margin effect) and increase the developmental productivity of whatever share remains (an intensive-margin effect, tested here).

These considerations yield four hypotheses. H1: Islamic banking depth is positively associated with SDG achievement, with the strongest association for SDG9. H2 (digital amplifier hypothesis): internet penetration positively moderates the association between Islamic banking depth and SDG achievement. H3: the amplification in H2 is distributionally heterogeneous and larger among catching-up economies. H4: the amplification is specific to the SDGs most directly tied to real-sector, formal-economy financing.[7]

1.4. The Case for Quantile Estimation

A conditional-mean regression would recover only the average moderating effect across the sample, obscuring precisely the distributional question this paper is designed to answer. The MMQR estimator of Machado and Santos Silva, an extension of the quantile framework of Koenker and Bassett to panels with individual fixed effects, estimates the effect of each regressor across the full conditional distribution through a location-scale specification. This is well suited to H3, and it complements causality-based approaches applied to comparable Islamic finance-sustainability panels.[8]

2. Materials and Methods

2.1. Sample, Variables and Sources

The paper uses an annual panel of up to 57 countries over 2007-2024. Islamic banking depth (IBA, percentage of total banking assets) is sourced from the Islamic Financial Services Board Prudential and Structural Islamic Financial Indicators. Internet penetration (percentage of population using the internet) is sourced from the International Telecommunication Union via the World Bank World Development Indicators. The five SDG outcome variables - SDG1 (no poverty), SDG7 (affordable and clean energy), SDG8 (decent work and economic growth), SDG9 (industry, innovation and infrastructure) and SDG10 (reduced inequalities), each scored on a 0-100 achievement scale - are sourced from the Sustainable Development Report (Sachs, Lafortune and Fuller 2025). Control variables (log GDP per capita, inflation, trade openness, and domestic credit to the private sector) are drawn from the World Bank World Development Indicators and the IMF World Economic Outlook. Table 1 reports descriptive statistics. TheTable 1. mean internet penetration rate of 48.2 percent, with a

standard deviation of 32.0 and a range from under 1 percent to 100 percent, provides substantial variation for identifying the interaction effect.[9]

Table 1. Descriptive statistics

Variable	N	Mean	SD	Min	Max
IBA (% of banking assets)	1,026	11.70	19.15	0.00	100.00
ln(IBA)	894	1.71	1.42	-2.30	4.61
Regulatory quality (WGI)	1,026	48.05	18.33	7.90	94.60
GDP per capita (log)	1,026	8.57	1.44	5.88	11.83
Inflation (%)	1,026	7.19	18.06	-12.56	359.09
Trade openness (% GDP)	1,026	91.17	75.40	2.00	442.60
Domestic credit to private sector (% GDP)	1,026	52.32	45.75	2.50	264.40
Mobile subscriptions (per 100)	1,026	105.38	44.65	6.10	364.85
Internet penetration (%)	1,026	48.22	32.01	0.39	100.00
Muslim population share (%)	1,026	66.78	36.93	0.10	100.00

2.2. Model Specification

The baseline specification regresses each SDG score on Islamic banking depth and controls. The interaction model, estimated for SDG9 as the primary outcome and extended to the remaining four goals, adds internet penetration and an IBA*internet term:

$$SDG(i,t) = b1*IBA(i,t) + b2*INTERNET(i,t) + b3*(IBA*INTERNET)(i,t) + gX(i,t) + a(i) + e(i,t)$$

The coefficient of interest is b3: a positive and significant b3 indicates that the marginal association between Islamic banking depth and SDG achievement rises with internet penetration, supporting the complementarity mechanism. The marginal effect of IBA is then given by b1 + b3*INTERNET, evaluated at policy-relevant levels of internet penetration.[10]

2.3. Estimation Strategy

The primary estimator is MMQR with country fixed effects, estimated at the 10th, 25th, 50th, 75th and 90th percentiles of each SDG outcome distribution. MMQR is preferred to conditional-mean panel estimators for two reasons. First, macro-financial panels of this kind routinely exhibit cross-sectional dependence and slope heterogeneity, both of which MMQR accommodates better than pooled OLS. Second, and centrally for H3, MMQR recovers the full conditional distribution rather than a single average effect. The MMQR results are corroborated with three cross-sectional-dependence-robust estimators applied to the baseline specification: fixed effects with Driscoll-Kraay standard errors (Driscoll and Kraay 1998), feasible generalized least squares (FGLS), and panel-corrected standard errors (PCSE). All models were estimated in Stata; MMQR was implemented via the mmqreg command with country fixed effects.[11]

3. Results

3.1 Baseline Association: Islamic Banking and SDG9

Table 2 reports the baseline MMQR results for SDG9, estimated without the internet interaction term. Islamic banking depth is positive and highly significant across the entire SDG9 distribution, supporting H1. The coefficient rises monotonically from 1.125 at the 10th percentile to 1.266 at the 90th percentile, with a median coefficient of 1.196 ($p < 0.01$). Domestic credit to the private sector is positive, significant and essentially stable across quantiles (0.187 to 0.191), indicating that the Islamic banking association with SDG9 holds independently of, and is not proxying for, general financial deepening. GDP per capita is, as expected, the dominant structural correlate of SDG9, with a coefficient rising from 4.264 at the 10th percentile to 7.834 at the 90th.

Table 2. Baseline MMQR results for SDG9

Variable	Q10	Q25	Q50	Q75	Q90
IBA	1.125***	1.151***	1.195***	1.237***	1.266***
	(0.096)	(0.083)	(0.080)	(0.100)	(0.122)
ln(GDP per capita)	4.264***	4.924***	6.045***	7.099***	7.834***
	(1.472)	(1.272)	(1.229)	(1.530)	(1.862)
Inflation	0.009	0.026	0.054*	0.081**	0.099**
	(0.034)	(0.029)	(0.028)	(0.035)	(0.042)
Trade openness	-0.003	0.005	0.020	0.034**	0.043**
	(0.015)	(0.013)	(0.012)	(0.015)	(0.019)
Private credit	0.187***	0.188***	0.189***	0.190***	0.191***
	(0.033)	(0.029)	(0.028)	(0.035)	(0.042)
N	846	846	846	846	846

Extending the baseline specification to the remaining four goals, Islamic banking depth is positive and significant for all five SDGs, with the largest coefficient for SDG9. This pattern is consistent with a selective-channels reading in which Islamic banking depth matters most for the goals most directly tied to real-sector, asset-backed financing.[12]

3.2 The Digital Amplifier: IBA*Internet Interaction

Table 3 reports the core interaction result, comparing the baseline specification with the interaction specification at the median quantile. Two results warrant emphasis. First, the IBA*internet interaction term is positive and significant ($b = 0.001$, $p < 0.01$), supporting H2: the marginal association between Islamic banking depth and SDG9 achievement rises with internet penetration, consistent with the complementarity mechanism rather than the substitution mechanism operating at the intensive margin. Using the marginal-effects formula, the estimated marginal effect is 0.174 + 0.001*INTERNET. At zero internet penetration the marginal effect is approximately 0.174; at the sample-mean penetration of 48.2 percent it rises to approximately 0.222, roughly 28 percent larger; and at Uzbekistan current penetration of approximately 90 percent it rises to approximately 0.264, roughly 52 percent larger than the near-zero-internet benchmark.[13]

Table 3. Baseline versus interaction specification, SDG9 (median quantile)

Variable	(1) Baseline	(2) Interaction
IBA	1.195*** (0.080)	0.174*** (0.045)
Internet penetration	—	0.375*** (0.010)
IBA × Internet	—	0.001*** (0.000)
ln(GDP per capita)	6.045*** (1.229)	-0.569 (0.660)
Private credit	0.189*** (0.028)	0.067*** (0.016)
N	846	846

Second, the raw IBA coefficient falls from 1.195 in the baseline to 0.174 once internet penetration and the interaction term are added. This reflects that internet penetration is itself strongly correlated with income level and absorbs a substantial share of the variance previously attributed to IBA and GDP per capita jointly; it does not imply that the baseline association is spurious, since the interaction specification tests a conceptually distinct question - whether the marginal effect of IBA depends on internet penetration - rather than re-estimating the same unconditional association.

3.3 Quantile Heterogeneity of the Amplifier

The digital amplifier effect is not uniform across the SDG9 distribution, supporting H3. As reported in Table 4, the interaction is significant at the 1 percent level from the 10th through the 50th percentile, weakens to the 5 percent level at the 75th percentile, and becomes statistically indistinguishable from zero at the 90th percentile. This is consistent with a catch-up interpretation: the amplifier is most important precisely among countries that have the most SDG9 ground to make up, where additional real-sector financing, made more efficient by digital rails, has the largest marginal payoff. Among countries already at the frontier, further gains depend on factors - advanced manufacturing capacity, research intensity, infrastructure maintenance - that are less sensitive to the interaction between financial-sector composition and digital penetration.[14]

Table 4. Quantile heterogeneity of the digital amplifier, SDG9

Variable	Q10	Q25	Q50	Q75	Q90
IBA	0.173*** (0.062)	0.173*** (0.052)	0.174*** (0.045)	0.175*** (0.051)	0.176*** (0.062)
Internet penetration	0.376*** (0.013)	0.375*** (0.011)	0.375*** (0.010)	0.375*** (0.011)	0.375*** (0.013)
IBA × Internet	0.001*** (0.000)	0.001*** (0.000)	0.001*** (0.000)	0.001** (0.000)	0.000 (0.000)
N	846	846	846	846	846

It is notable that the direct IBA coefficient in the interaction specification is essentially flat across quantiles (0.173 to 0.176), in contrast to the rising pattern in the baseline. Once internet penetration and its interaction are controlled for, the apparent quantile-dependence of the raw IBA effect is substantially explained by the fact that high-SDG9 countries also tend to have high internet penetration; the quantile-dependence that remains resides principally in the interaction term itself - the pattern implied by a genuine amplification mechanism rather than an omitted-variable artifact.

3.4 Cross-SDG Generalizability

The Table 5. digital amplifier effect is specific to SDG8 and SDG9 and is not detected for SDG1, SDG7 or SDG10, supporting H4. This selectivity is theoretically coherent: SDG8 and SDG9 are the two goals most directly tied to the formal-sector, real-economy financing that Islamic banking is structurally oriented toward and that digital infrastructure most directly facilitates - digital trade finance, supply-chain financing platforms, digitized project appraisal and disbursement. Poverty reduction and reduced inequality plausibly operate more through direct household-level financial inclusion and redistributive instruments such as zakat and qard hasan than through project-finance activities, while clean energy is driven predominantly by technology policy and capital intensity rather than by the composition of bank financing. The interaction for SDG8, while statistically significant, is small in absolute magnitude and should be interpreted with corresponding caution.

Table 5. Digital amplifier across five SDGs (median quantile)

Variable	SDG1	SDG7	SDG8	SDG9	SDG10
IBA	0.220**	0.204	-0.019	0.174***	0.345
	(0.106)	(0.176)	(0.019)	(0.045)	(0.335)
Internet penetration	0.065***	0.062	0.033***	0.375***	0.016
	(0.016)	(0.040)	(0.005)	(0.010)	(0.046)
IBA × Internet	-0.000	-0.001	0.000***	0.001***	0.003
	(0.000)	(0.001)	(0.000)	(0.000)	(0.003)
N	714	846	846	846	722

3.5 Robustness

The sign of the baseline IBA-SDG9 and IBA-SDG1 associations is positive across all three cross-sectional-dependence-robust estimators, and both are significant under Driscoll-Kraay and FGLS. The PCSE estimator, which imposes a common AR(1) structure across all panels, renders both coefficients statistically insignificant. This paper treats the PCSE result as a specification-sensitivity caveat rather than as evidence against the baseline association, while reporting it transparently. The interaction term itself was estimated via MMQR; extending the alternative estimators to the interaction specification is identified as a direction for further work.[15]

4. Discussion

The central finding is that internet penetration and Islamic banking depth are complements, not substitutes, in their joint association with SDG9 achievement. Read alongside evidence that internet penetration is associated with a smaller Islamic banking market share in established markets, the results imply a two-margin story: digital infrastructure may constrain how large the Islamic banking sector becomes, while simultaneously increasing how much real-economy development a given unit of Islamic banking depth delivers. This distinction matters for policy, because it implies that concerns about digital infrastructure crowding out Islamic banking market share should not be read as concerns about digital infrastructure undermining its developmental value.

The quantile heterogeneity documented in Section 4.3 - a digital amplifier that is strong among catching-up economies and indistinguishable from zero among frontier economies - is consistent with a diminishing-returns interpretation. Where physical and digital infrastructure are already extensive, additional financing, however efficiently

delivered, faces a shrinking marginal opportunity set; where infrastructure is still being built, digitally efficient financing has more unrealized development to unlock.

The goal-specificity documented in Section 4.4 reinforces a selective-channels reading of the contribution of Islamic finance to sustainable development. Rather than treating Islamic finance as a generic sustainability input best summarized by a composite index, the evidence points toward specific, theoretically motivated channels: real-sector, asset-backed financing maps onto industry and infrastructure and, to a lesser extent, decent work; it does not map as directly onto poverty, inequality or clean energy, which appear to be driven by other channels. This selectivity should temper both the direction of future measurement - goal-specific rather than composite-index designs - and the ambitions attached to Islamic finance and digitalization reform packages.

4.1 Policy Implications for Uzbekistan

Uzbekistan occupies an unusual position in this sample. On the internet-penetration dimension it is firmly in the upper portion: penetration reached approximately 89 percent of the population in 2023-2024 and an estimated 93-94 percent by mid-2025 well above the sample mean of 48.2 percent. On the Islamic banking dimension it sits at the opposite extreme: the Law on Islamic Banking entered into legal force on 28 June 2026, establishing for the first time a legal and regulatory pathway - including a dedicated Council on Islamic Finance under the Central Bank - for licensed Islamic banks, Islamic windows within existing conventional banks, and full conversion of conventional banks to Sharia-compliant status.

The results speak directly to how this sequencing should be read. The amplifier effect implies that, as the Islamic banking sector develops from a near-zero base, each percentage point of depth it accumulates should generate a larger SDG9 dividend than the sample average, precisely because internet penetration is already close to the sample maximum: the estimated marginal effect at approximately 90 percent penetration (about 0.264) is roughly 19 percent above the sample-average marginal effect (about 0.222) and roughly 52 percent above the near-zero-internet benchmark. The quantile heterogeneity implies that this amplification should be strongest precisely for a country whose SDG9 score remains below the cross-country median.

Three caveats temper this reading. First, the coefficients are estimated on a cross-country panel and extrapolated to a single country whose regulatory design, initial bank composition and macroeconomic conditions may cause its realized experience to diverge from the panel-average marginal effect; the calculation conveys an order of magnitude, not a forecast. Second, the interaction is identified from cross-country variation over 2007-2024, a period during which very few sample countries combined near-zero IBA with near-90-percent internet penetration simultaneously; the Uzbek combination therefore lies partly outside the historically observed joint support of the two regressors. Third, the amplification mechanism is proposed theoretically and is not directly tested with instrument-level data.

With these caveats stated, the practical implication is that the Uzbek sequencing - building near-universal digital infrastructure ahead of a legally permissible Islamic banking sector - is, on this evidence, a favorable rather than an adverse sequence for the eventual contribution of the sector to industrial and infrastructural development. There is no evidence here to support delaying digital-infrastructure investment out of concern that it would undercut the developmental payoff of a nascent Islamic banking sector. If anything, the coincidence of timing offers the newly formed Council on Islamic Finance an opportunity to design the digital channels of the sector - digital sukuk platforms, integrated payments for Islamic windows, digitized Sharia-compliant trade finance - as native features from the earliest licensing decisions rather than as later retrofits.

5. Conclusion

This paper examines whether digital infrastructure amplifies or substitutes for the developmental contribution of Islamic banking, using an annual panel of up to 57 countries over 2007-2024 and Method of Moments Quantile Regression as the primary estimator. Islamic banking depth is positively associated with all five Sustainable Development Goals examined, most strongly with SDG9. Once internet penetration and an IBA*internet interaction term are introduced, the interaction is positive and significant for SDG9: internet penetration amplifies rather than displaces the association between Islamic banking and industrial and infrastructural development. This amplification is concentrated in the lower and middle quantiles of the SDG9 distribution and is goal-specific, appearing for SDG8 and SDG9 but not for SDG1, SDG7 or SDG10.

These findings carry direct relevance for Uzbekistan, which combines internet penetration near the top of the sample distribution with an Islamic banking sector that became legally permissible only in June 2026. On this evidence, that sequencing is favorable to the eventual contribution of the sector to SDG9, though the magnitude of the realized effect should be treated as illustrative rather than predictive.

Several limitations qualify these conclusions. First, the design is observational and cross-country; the associations documented here should not be read causally. Second, the Driscoll-Kraay, FGLS and PCSE robustness layer was applied to the baseline specification but not extended to the interaction specification; doing so, along with a system-GMM dynamic specification to test persistence and potential endogeneity, is a natural next step. Third, the Islamic banking asset share is a bank-based proxy that does not capture the broader Islamic finance ecosystem - sukuk markets, takaful and Islamic asset management - through which digital amplification may also operate. Extending the interaction design to these instruments, as digital sukuk platforms and comparable data become available, is a promising direction for future research.

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