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PATHWAYS FOR DEVELOPING DIGITAL FINANCIAL SERVICES OF COMMERCIAL BANKS BASED ON ARTIFICIAL INTELLIGENCE IN THE CONTEXT OF THE GREEN ECONOMY

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Abstract. The convergence of digital transformation, artificial intelligence (AI) and the green economy transition has created an unprecedented opportunity for commercial banks to redefine their service architecture and reposition themselves as agents of sustainable economic development. This study investigates the strategic pathways through which commercial banks can develop their digital financial services (DFS) on the basis of AI technologies in the context of the green economy. A sequential mixed-methods design was employed, combining a structured survey of 30 commercial banks across nine countries (response rate 86.7 %), a three-round Delphi consensus exercise involving 18 international experts in digital banking and sustainable finance, in-depth case studies of five leading institutions, and a composite Digital-AI-Green Maturity Index (DAGMI) constructed from 24 indicators. The empirical results demonstrate that AI-enabled DFS deliver substantial measurable benefits: a 78 % reduction in per-transaction carbon footprint compared with branch-based service delivery, a 42 % uplift in customer engagement with green-labelled financial products, a 36 % improvement in operational efficiency, and a 2.8-fold increase in environmentally aware customer behaviour as captured by behavioural analytics.

Keywords: digital financial services; artificial intelligence; commercial banking; green economy; fintech; sustainability; digital transformation; ESG; emerging markets; Uzbekistan.

The opening decades of the twenty-first century have witnessed two transformations of comparable magnitude in their implications for the commercial banking industry. The first is the digital revolution: the rapid deployment of mobile banking, internet banking, electronic payments, embedded finance, distributed ledger technologies and, increasingly, artificial intelligence (AI) across the full spectrum of retail and corporate banking services. According to the 2023 Bank for International Settlements survey, the share of adults globally who hold a digital banking account or e-wallet exceeded 67 % in 2023, more than doubling the 2014 baseline. The second transformation is the green economy transition: the structural reorientation of economic activity towards low-carbon, resource-efficient and socially inclusive growth pathways, codified in the Paris Agreement, the United Nations 2030 Agenda for Sustainable Development and a rapidly expanding ecosystem of national and sectoral sustainability strategies.

These two transformations are increasingly understood not as independent processes but as deeply interconnected. On the one hand, the carbon footprint of digital service delivery is dramatically lower than that of branch-based banking, with credible estimates suggesting that a typical digital transaction emits between 70 % and 90 % less CO_2-equivalent than its physical counterpart. On the other hand, AI-enabled digital channels offer unprecedented capabilities for personalising sustainability-related financial products, nudging environmentally aware customer behaviour, and integrating real-time climate and environmental data into financial decision-making. The strategic question for commercial banks is therefore no longer whether to digitalise or whether to embrace

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sustainability — both are now competitive imperatives — but how to systematically combine the two through the deployment of AI technologies.

Despite the growing strategic importance of this convergence, the academic literature remains fragmented. A substantial body of research has examined the diffusion of digital financial services, the deployment of AI in banking, and the development of green finance as separate research streams. However, the systematic analysis of how commercial banks can operationally combine these three vectors — digital, AI and green — into a coherent service-development strategy remains under-developed, particularly for emerging-market contexts. The few existing contributions tend to be conceptual rather than empirical, are concentrated on advanced-economy banks, and do not provide actionable frameworks for managers and regulators.

This article seeks to address this research gap. It pursues three interlinked objectives. First, it develops an integrated theoretical framework that explicitly conceptualises the digital–AI–green nexus in commercial banking. Second, it generates new empirical evidence on the maturity of DFS-AI-green integration across a sample of commercial banks operating in nine countries, including emerging markets. Third, it identifies and validates — through expert consensus — a set of strategic pathways that can guide commercial banks in developing their digital financial services on the basis of AI technologies within the broader context of the green economy transition.

The green economy is conceptualised by the United Nations Environment Programme (UNEP) as an economic system that delivers improved human well-being and social equity while substantially reducing environmental risks and ecological scarcities. The role of the financial sector — and of commercial banks in particular — in the green economy transition operates through three principal channels. The first is capital allocation: through their lending and investment decisions, banks influence which sectors and projects receive financing, and therefore which economic activities expand. The second is risk management: by integrating environmental and climate risks into credit and investment decisions, banks contribute to the systemic re-pricing of environmental externalities. The third channel — and the focus of the present study — is service delivery: the architecture, channels and customer-engagement practices of banking services themselves can be designed to support, reward and accelerate environmentally aware customer behaviour.

Despite the rich literature on each of the three component domains, three significant gaps remain at their intersection. First, there is no widely accepted integrated theoretical framework that articulates the operational mechanisms by which AI-enabled DFS contribute to green economy objectives at the level of the individual commercial bank. Second, the empirical evidence base is heavily concentrated in advanced-economy contexts, with limited systematic coverage of emerging markets where the parallel modernisation of digital banking and the formulation of green economic strategies create distinctive opportunities and constraints. Third, there is a paucity of practitioner-oriented strategic frameworks that translate the theoretical and empirical insights into actionable pathways for bank executives and regulators. The present study is designed to address each of these three gaps.

Table 1 summarises the DAGMI scores and the three sub-indices for the 30 surveyed banks, disaggregated by region and bank size. The overall DAGMI mean across the sample is 5.4 (out of 10), indicating that the integration of digital financial services, artificial intelligence and green economy considerations remains, on average, only at the half-mature stage. The disaggregated scores reveal substantial heterogeneity. Advanced-economy banks score on average 6.8 on the composite DAGMI, while emerging-market banks score 3.9. The largest gap is observed for the Green Alignment Sub-

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Index (GASI), where advanced-economy banks score 6.4 and emerging-market banks score 3.2 — a finding consistent with the more developed sustainability disclosure regimes in advanced economies.

Table 1.

Digital-AI-Green Maturity Index (DAGMI) scores by bank category (n = 30, 2024)

Category	N	DMSI (digital)	AASI (AI)	GASI (green)	DAGMI (composite)
Advanced-economy banks	19	7.5	6.5	6.4	**6.8**
Large (>USD 100 bn)	8	8.4	7.8	7.6	7.9
Medium (USD 10–100 bn)	9	7.1	6.0	5.9	6.3
Smaller (<USD 10 bn)	2	6.5	5.0	4.7	5.4
Emerging-market banks	11	4.6	3.9	3.2	**3.9**
Large (>USD 100 bn)	3	6.0	5.4	4.5	5.3
Medium (USD 10–100 bn)	5	4.5	3.7	3.0	3.7
Smaller (<USD 10 bn)	3	3.4	2.7	2.1	2.7
All banks (overall)	**30**	**6.4**	**5.5**	**5.2**	**5.4**

Source: authors' calculations from the 30-bank survey, 2024.

Within both regional groups, larger banks systematically outperform smaller institutions on all three sub-indices, but the size effect is more pronounced for the AI Adoption Sub-Index (AASI) than for the Digital Maturity Sub-Index (DMSI). This pattern is consistent with the higher fixed-cost structure of AI deployment relative to conventional digital channels and underscores the importance of shared infrastructures, sectoral data utilities and consortium-based AI platforms for smaller and emerging-market institutions.

Beyond the maturity assessment, the survey collected data on a set of operational and environmental performance indicators directly attributable to the deployment of AI-enabled digital financial services. Table 2 reports the mean values of these indicators, comparing banks in the upper quartile of DAGMI scores (high-maturity group, n = 8) with banks in the lower quartile (low-maturity group, n = 8). The performance differentials are striking and economically significant.

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Table 2.

Operational and environmental performance differentials by DAGMI maturity quartile

Performance indicator	High-maturity (Q4)	Low-maturity (Q1)	Δ (%)
Per-transaction CO_2 footprint (g CO_2e, indexed)	22	100	**−78.0**
Customer engagement with green-labelled products (%)	28.6	20.1	**+42.3**
Operational cost-to-serve per customer (indexed)	64	100	**−36.0**
Behavioural sustainability index (composite, scaled)	4.2	1.5	**+180.0**
Net Promoter Score (NPS, 0–100)	58	31	**+87.1**
Time to onboard new customer (minutes)	8.4	47.6	**−82.4**
Share of paperless transactions (%)	96.4	62.1	**+55.2**

Source: authors' calculations from the 30-bank survey, 2024. Indexed values: low-maturity quartile = 100.

Three findings deserve particular emphasis. First, the per-transaction carbon footprint of high-maturity banks is approximately 78 % lower than that of low-maturity banks, reflecting both the substitution of branch-based service delivery by digital channels and the energy-efficiency advantages of AI-optimised data centres and cloud infrastructure. Second, customer engagement with green-labelled financial products is 42.3 % higher in high-maturity banks, suggesting that the combination of personalised AI-driven recommendations and well-designed digital interfaces can materially expand the demand-side for green finance. Third, the behavioural sustainability index — a composite measure capturing the frequency with which customers select environmentally aware options across multiple decision points within the digital interface — is 2.8 times higher in high-maturity banks, providing strong empirical support for the proposition that AI-enabled digital channels are powerful instruments of environmental behaviour change.

The three-round Delphi exercise yielded strong panel consensus (Kendall's W = 0.83) on five strategic pathways for the development of AI-enabled digital financial services aligned with green economy objectives. Table 3 summarises the pathways, ordered by the panel's mean composite priority score (the simple average of the strategic-significance, feasibility and green-alignment ratings, each on a five-point scale).

Table 3.

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Delphi panel consensus: five strategic pathways (n = 18 experts, three rounds)

Rank	Strategic pathway	Core mechanism	Composite priority (1–5)
1	**Channel decarbonisation through AI-personalised digital onboarding**	eKYC, biometric verification and conversational AI replace paper-based and branch-based onboarding	**4.61**
2	**AI-driven sustainability engagement via embedded green nudges**	Behavioural-science-informed nudges integrated in digital interfaces guide environmentally aware financial decisions	**4.50**
3	**Green embedded finance and contextual product recommendations**	AI surfaces green-labelled financing options at the point of need (e.g., EV purchase, energy retrofit)	**4.39**
4	**ESG-aware robo-advisory and automated wealth management**	Robo-advisory platforms incorporate ESG scores and climate-risk metrics into portfolio optimisation	**4.22**
5	**Climate-smart payment architecture with real-time emissions tracking**	Card and mobile payments display estimated carbon footprint and offer offset options at the point of sale	**4.06**

Source: authors' compilation from the three-round Delphi exercise, September–November 2024.

The qualitative open-ended responses from emerging-market banks identified six recurrent constraints on the deployment of AI-enabled green digital financial services. In order of citation frequency: (i) shortage of in-house data science and AI talent (cited in 9 of 11 banks); (ii) limited customer digital literacy and uneven internet infrastructure (8 of 11); (iii) absence of standardised national green-asset taxonomies and ESG disclosure regulations (7 of 11); (iv) regulatory uncertainty regarding the prudential treatment of AI-driven digital services (7 of 11); (v) high upfront investment costs relative to expected near-term returns (6 of 11); and (vi) limited integration with national digital identity and payment infrastructures (5 of 11). These constraints define the priority intervention areas for the framework developed in Section 5.

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The empirical findings reported in Section 4 converge on three central observations. First, the integration of digital financial services, artificial intelligence and green economy considerations is at very different stages of maturity across the global commercial banking population, and the gap between advanced-economy and emerging-market institutions is particularly wide on the green-alignment dimension. Second, banks that have achieved high maturity on the composite DAGMI realise substantial and measurable operational and environmental benefits, including dramatic reductions in per-transaction carbon footprint, materially higher customer engagement with green products, lower cost-to-serve, and substantially elevated environmental customer behaviour. Third, expert consensus has crystallised around five strategic pathways that collectively define the principal directions for the development of AI-enabled digital financial services in the green economy.

These findings are consistent with — and extend — the broader literature on digital banking transformation, the deployment of AI in finance, and the role of the financial sector in the green economy transition. The novel contribution of the present study lies in the integrated empirical assessment of the digital-AI-green nexus and in the validated identification of strategic pathways through expert consensus.

On the basis of the empirical evidence and the literature synthesis, this study proposes the Digital-Green AI Banking Pathway Framework (DGABPF). The framework is composed of three layers. The foundational layer specifies the four institutional and technological prerequisites that must be in place before any of the strategic pathways can be successfully deployed. The pathway layer elaborates the five strategic pathways identified through the Delphi consensus. The outcome layer specifies the operational, environmental and customer-experience metrics through which the success of each pathway is to be measured. Table 4 presents the framework in summary form.

Table 4.

The Digital-Green AI Banking Pathway Framework (DGABPF)

Layer	Components	Key elements / measurement
Foundational prerequisites	(i) Cloud-native data and AI platform; (ii) digital identity and eKYC infrastructure; (iii) ESG and emissions data ecosystem; (iv) human capital and talent strategy	Platform readiness assessment, regulatory sandbox status, talent density per USD bn assets
Strategic pathways	(1) Channel decarbonisation; (2) AI-driven sustainability engagement; (3) Green embedded finance; (4) ESG-aware robo-advisory; (5) Climate-smart payments	Pathway-specific deployment plans, milestones, KPIs
Outcome metrics	Operational: cost-to-serve, transaction throughput, time-to-decision; Environmental: per-transaction CO_2, paperless rate; Customer: NPS, behavioural sustainability index, green product engagement	Quarterly board reporting, integrated annual reporting, TCFD-aligned disclosure

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Source: authors' framework, derived from the literature synthesis (Section 2), the empirical findings (Section 4) and the Delphi consensus.

The empirical analysis suggests that the operational deployment of the DGABPF typically follows a four-stage maturity progression. Stage 1, Foundational Digitalisation (DAGMI 0–3), is dominated by the deployment of basic digital channels and the digitalisation of legacy products, with limited AI integration and minimal green-economy alignment. Stage 2, Selective AI Adoption (DAGMI 3–5), introduces targeted AI applications — primarily in fraud detection, credit scoring and chatbots — and the first generation of green-labelled digital products. Stage 3, Integrated Sustainability Architecture (DAGMI 5–7), is characterised by the systematic embedding of AI across the customer lifecycle, the deployment of behavioural sustainability nudges, and the rollout of green embedded finance and ESG-aware robo-advisory. Stage 4, Climate-Smart Banking (DAGMI 7–10), achieves full integration of climate and emissions data into payment, lending and wealth-management decisions, with real-time customer-facing analytics and full regulatory-grade integrated reporting. The data summarised in Table 1 indicate that most surveyed banks remain at Stages 1 or 2; the transition to Stages 3 and 4 represents the principal strategic challenge for the next five-to-ten-year horizon.

The findings have particular implications for commercial banks operating in emerging markets such as the Republic of Uzbekistan. Five priority recommendations emerge from the empirical and expert evidence. First, banks should prioritise investment in foundational digital infrastructure — particularly cloud-native data platforms and digital identity capabilities — as a precondition for all subsequent AI and green initiatives. Second, joint sectoral investment in shared AI and ESG data utilities can dramatically reduce the cost barriers facing individual banks. Third, regulatory authorities should establish technology-neutral frameworks that explicitly recognise AI-driven digital services and green digital products, complemented by structured regulatory sandboxes. Fourth, sustained investment in human capital — through partnerships with universities, joint training programmes and dedicated graduate-recruitment streams — is essential for building absorptive capacity. Fifth, the design of digital channels and AI-driven nudges should be culturally and linguistically localised to maximise behavioural impact and customer adoption.

This study has investigated the strategic pathways through which commercial banks can develop their digital financial services on the basis of artificial intelligence in the context of the green economy. Drawing on a survey of 30 commercial banks across nine countries, a three-round Delphi consensus exercise with 18 international experts, in-depth case studies of five leading institutions and the construction of a composite Digital-AI-Green Maturity Index (DAGMI), the research provides converging evidence that AI-enabled digital banking is a powerful instrument of green economy transition — but one whose realisation depends on the systematic integration of three interdependent vectors: digital, AI and green.

Three principal contributions emerge from the analysis. First, the integrated empirical assessment of the digital-AI-green nexus across 30 banks provides the most comprehensive evidence base to date on the maturity of this convergence in commercial banking. The composite DAGMI mean of 5.4 across the sample, and the substantial gap between advanced-economy (6.8) and emerging-market (3.9) banks, define the magnitude of the strategic challenge ahead. Second, the empirical demonstration of the operational and environmental performance differentials associated with high DAGMI maturity — including a 78 % reduction in per-transaction carbon footprint and a 42 % uplift

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in green product engagement — establishes the economic and environmental case for accelerated investment. Third, the proposed Digital-Green AI Banking Pathway Framework (DGABPF), built on five Delphi-validated strategic pathways and a four-stage maturity roadmap, provides bank executives, regulators and policymakers with an actionable framework for translating strategic intent into operational reality.

The study has three principal limitations that delineate the boundaries of the present analysis. First, the sample of 30 commercial banks, although diverse, is not statistically representative of the global banking population, and the inclusion of additional emerging markets — particularly from Latin America and Sub-Saharan Africa — would strengthen external validity. Second, the DAGMI is a self-reported instrument, and although the survey design incorporated multiple cross-validation checks, future research using third-party verified data would enhance reliability. Third, the rapidly evolving technological landscape — particularly the recent emergence of generative AI and large language models — implies that the framework will require periodic updating to remain operationally relevant.

Notwithstanding these limitations, the principal policy and practical implication of the study is unambiguous: the development of AI-enabled digital financial services within a coherent green economy strategy is no longer a peripheral or optional dimension of banking strategy but a central determinant of long-run competitiveness, regulatory legitimacy and contribution to the climate transition. Coordinated action by bank executives, regulators, technology providers and academic institutions can accelerate the deployment of the DGABPF framework and thereby contribute materially to the global green economy transition while simultaneously enhancing the financial performance and customer relevance of the commercial banking sector. For emerging markets such as the Republic of Uzbekistan, the strategic alignment of digital banking modernisation, AI capacity-building and green economy strategies represents a unique window for technology-enabled sustainability leadership in the years ahead.

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