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An Optimization-Based Framework for Gamification in FinTech: Enhancing Customer Loyalty and Advancing SDG Targets

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Abstract:
This study develops an optimization-based framework for gamification in financial technology (FinTech) to enhance customer loyalty and advance Sustainable Development Goals (SDGs). By synthesizing data from 33 empirical studies conducted between 2015 and 2025, a meta-analysis using the SidikJonkman random-effects model was performed to evaluate the effectiveness of gamification and optimization strategies in digital finance. The findings demonstrate that gamification features in FinTech platforms significantly strengthen customer loyalty ($\beta = 5.066$, $p < 0.001$), highlighting the central role of engagement mechanisms such as points, rewards, and leaderboards. The residual heterogeneity estimates ($\tau^2 = 0.002$; $I^2 = 0.604\%$) reveal low variability across studies, confirming the efficiency and reliability of optimization-driven gamification strategies. Moreover, results indicate that FinTech innovations contribute positively to sustainable development outcomes, with optimization-based gamification mediating between FinTech adoption and SDG achievements. The absence of publication bias (Egger's test: $z = -0.543$, $p = 0.587$) further reinforces the robustness of the findings. This study provides strong empirical evidence that integrating gamification with optimization techniques fosters customer loyalty and aligns digital finance practices with global sustainability priorities. It advances theoretical understanding of how digital engagement tools interact with optimization methods to produce measurable social and economic outcomes. It also offers actionable insights for researchers, policymakers, and industry practitioners. The framework opens new pathways for designing customer-centric FinTech solutions that drive business growth and contribute to realizing SDGs.

Keywords: FinTech, Gamification, Customer Loyalty, Optimization, Digital Financial Services, Sustainable Development Goals.
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1 Introduction

The rapid growth of FinTech has revolutionized the global financial services industry, enabling faster, more inclusive, and data-driven solutions [1]. The global FinTech market is expected to reach $324 billion by 2026, growing at a compound annual growth rate of nearly 25%. Despite this exponential growth, one of the primary challenges facing FinTech firms is retaining customers and building long-term loyalty, given the high competition and rapid technological advancements. This challenge has prompted researchers and practitioners to explore innovative approaches to enhance the customer experience and foster sustainable engagement in digital finance ecosystems [2]. One promising strategy that has gained attention in recent years is gamificationusing game design elements, such as points, badges, leaderboards, and rewards, in non-game contexts to enhance user engagement [3]. Deterding et al. [4] defined gamification as "the use of game design elements in non-game contexts" to increase user motivation and participation. In the FinTech domain, gamification has been employed in applications such as personal finance management, digital banking, and investment platforms to make financial services interactive, enjoyable, and customer-centric [5]. For instance, apps like Revolut and Monzo use gamified savings challenges to encourage customers toward better financial habits, directly influencing customer loyalty and retention [6].

However, the design and implementation of gamification strategies require careful optimization to ensure that customer experience, business goals, and sustainability objectives are balanced effectively [7–9]. Traditional gamification approaches often focus solely on user engagement, neglecting the broader implications for sustainable development and long-term customer relationships cite 10. FinTech companies can systematically allocate resources by integrating optimization techniques, personalizing user experiences, and maximizing engagement outcomes while aligning with organizational social objectives such as the United Nations SDGs [11, 12]. The SDGs, introduced in 2015, represent a universal call to action to address global challenges, including poverty, inequality, climate change, and economic growth. FinTech innovations have the potential to significantly contribute to achieving SDG targetsparticularly SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production)by promoting financial inclusion, green finance, and sustainable economic ecosystems. When optimized effectively, gamification can encourage customers to adopt eco-friendly financial behaviours, invest in sustainable projects, or engage with socially responsible financial products [13].

The motivation for this research arises from the need to bridge three critical domains: gamification, optimization techniques, and sustainability in the context of FinTech innovation. While previous studies have explored gamification for customer

engagement, very few have examined how mathematical optimization methods can be integrated into gamified FinTech ecosystems to enhance customer loyalty and advance SDG objectives [10, 14]. Developing such a framework will provide theoretical contributions to the digital finance and sustainability literature and offer practical insights for FinTech companies seeking to differentiate themselves in an increasingly competitive landscape cite 15. Therefore, this study aims to propose an optimization-based framework for gamification in FinTech that enhances customer experience and loyalty while aligning digital financial services with sustainability principles and SDG targets. Combining behavioural insights, technological innovation, and optimization modelling, the research seeks to create a holistic framework that benefits businesses, customers, and society [16, 17].

The digital financial ecosystem is witnessing unprecedented growth, driven by technological advancements and changing consumer preferences [18]. Despite this progress, customer loyalty remains a critical challenge for FinTech service providers due to the highly competitive market and low customer switching costs [19]. By integrating play and engagement elements into financial services, gamification has emerged as a powerful tool to influence customer behavior, improve satisfaction, and foster loyalty [5, 20]. However, the existing literature broadly explores gamification in isolation, without considering the optimal design and sustainability implications of such strategies [10]. Moreover, the United Nations SDGs emphasise responsible innovation, financial inclusion, and sustainable economic growth (e.g., SDG 8, SDG 9, and SDG 12) [20]. FinTech platforms, when designed with optimisation models and sustainability principles, can align customer engagement strategies with these global objectives, encouraging environmentally and socially responsible financial behaviours [9, 21]. Conducting a meta-analysis of 33 empirical studies using the SidikJonkman method enables us to combine results across multiple contexts and evaluate the true effect sizes of gamification on customer experience, loyalty intention, and sustainability outcomes. Unlike narrative reviews, a meta-analysis offers quantitative evidence with higher statistical power, providing more accurate and generalizable insights into how gamification, when optimized, can be a transformative tool in FinTech innovation.

This study makes significant contributions across theoretical, methodological, and practical dimensions. From a theoretical perspective, it introduces an integrated optimization-based framework that links gamification, customer experience, loyalty intention, and sustainability outcomes within the context of FinTech innovation. The study bridges the gap between digital financial innovation and global sustainability objectives by aligning gamification strategies with United Nations SDGs, particularly financial inclusion, responsible consumption, and economic growth. A meta-analysis of various empirical studies provides robust evidence on the effectiveness of gamification in enhancing customer loyalty and promoting sustainable

financial behaviour, thereby contributing new insights to the literature on digital finance and sustainability-driven customer engagement. The study employs the SidikJonkman random-effects model, a robust statistical approach that can handle heterogeneity across multiple studies while generating unbiased pooled estimates of effect sizes. By using data elements such as Mean, Standard Deviation (SD), Standard Error (SE), and SS from each study, the analysis ensures higher statistical rigour and reliability. This approach also facilitates moderator and sensitivity analyses, enabling the identification of contextual factorssuch as the type of gamification mechanics, cultural settings, and platform characteristicsthat influence the relationship between gamification and customer loyalty outcomes.

From a practical perspective, the study offers valuable guidance for FinTech firms, policymakers, and application developers by providing an evidence-based optimization framework for designing gamification strategies that maximize customer engagement and loyalty while fostering sustainable financial practices. The findings will help stakeholders develop customer-centric, ethically responsible, and SDG-aligned FinTech ecosystems by integrating behavioral insights, optimization techniques, and sustainability principles, supporting business objectives and broader societal goals.

1.1 Research Gap

Despite the growing interest in gamification, customer loyalty, and sustainability in the FinTech sector, several critical gaps persist in the literature:

- Empirical research on the impact of gamification on customer loyalty and sustainability outcomes reports mixed and sometimes contradictory results, creating ambiguity for researchers and practitioners.

- Although narrative reviews exist, no comprehensive meta-analysis synthesizes empirical evidence across multiple studies using robust random-effects models such as the SidikJonkman method, which is particularly suited for addressing heterogeneity across studies.

- Most research focuses on behavioral aspects of gamification without applying mathematical optimization techniques to determine the best mix of gamification features for maximizing customer loyalty while advancing SDG targets.

- The link between gamification-driven customer engagement and sustainability outcomes (e.g., green finance adoption, financial inclusion) remains underex-

plored, especially in the context of FinTech innovations.

This study aims to provide theoretical advancement, methodological rigour, and practical relevance to academia, industry, and policy-making by addressing these gaps through a meta-analytic approach and proposing an optimisation-based gamification framework. The remaining part of this study is organized as follows. Section 2 presents the literature review, discussing gamification in FinTech, optimization approaches, and the role of FinTech in achieving SDGs. Section 3 outlines the research methodology, including research design, data collection procedures, and hypothesis development. Section 4 reports and discusses the meta-analysis results, highlighting the empirical findings related to gamification, optimization, and sustainability outcomes. Section 5 provides the conclusion, summarizing the key findings, discussing the study's limitations, and suggesting directions for future research.

2 Literature Review

2.1 Gamification in FinTech and Its Impact on Customer Loyalty

The global FinTech industry is expanding rapidly, with market estimates projecting a value of nearly USD 324 billion by 2026 at a CAGR of about 25% [22]. This rapid growth, however, has intensified competition among FinTech firms, making customer engagement and loyalty critical success factors [23]. In this context, gamification the integration of game elements into non-game settings has emerged as a promising strategy to enhance customer experience and retention [24]. Reports suggest that gamification can increase user engagement by up to 48% in digital platforms, indicating its potential to transform how customers interact with FinTech services [25]. Leading platforms such as Revolut, Monzo, and WeChat Pay have already incorporated gamified features like leaderboards, savings challenges, and reward-based incentives to encourage positive financial behaviour and build long-term customer relationships [6].

Gamification is defined as "using game design elements in non-game contexts to increase user engagement, motivation, and participation" [4]. FinTech involves points, badges, progress indicators, competitions, and real-time rewards to make financial activities more engaging and interactive [26]. The concept draws heavily on established behavioral and motivational theories, particularly Self-Determination Theory (SDT) [27] and Flow Theory [28]. SDT suggests that gamification is effective because it satisfies the innate psychological needs for competence, autonomy, and relatedness, thereby fostering intrinsic motivation [29]. Flow Theory [30] posits that well-structured challenges combined with immediate feedback create a state of

"flow," resulting in deep engagement and satisfaction during financial tasks. Empirical studies consistently highlight the positive impact of gamification on customer loyalty in FinTech ecosystems.

For instance, a study on WeChat Pay found that gamified financial services significantly improved customer engagement, loyalty intentions, and word-of-mouth behaviours across different age groups [21, 26]. A meta-analytic review on gamification in digital services further confirmed its effectiveness in improving customer satisfaction, trust, and loyalty, especially when gamified experiences included personalization and social interaction features [31]. By leveraging habit loops and instant gratification rewards, gamified financial platforms reinforce positive financial behaviours such as saving, budgeting, and responsible spending [10]. Moreover, elements like leaderboards and social competition enhance emotional engagement, making customers feel invested in the platform and reducing the likelihood of switching to competitors [32]. The endowment effect, where users value rewards or points they have earned more than equivalent rewards offered by competitors, further strengthens long-term loyalty [32].

The research demonstrates that gamification in FinTech enhances customer experience, drives engagement, and fosters behavioural change and loyalty intentions. However, most studies treat gamification as a stand-alone construct, with limited attention to how optimization models can systematically design gamified features or how these interventions can align with sustainability objectives and SDG targets [22]. Addressing these gaps provides the foundation for developing the present study's comprehensive optimization-based gamification framework. The review of gamification in FinTech and its impact on customer loyalty contributes to our study by establishing the theoretical and empirical foundation for linking game-based engagement strategies with customer experience, behavioral change, and loyalty intentions in digital financial platforms. By synthesizing findings from previous studies, this section highlights how gamification elementssuch as points, badges, rewards, challenges, and progress indicatorsenhance customer motivation, trust, and emotional attachment, ultimately leading to long-term platform retention. Importantly, the literature connects gamification with behavioral motivation theories like SDT and Flow Theory, providing a psychological explanation for why customers respond positively to gamified financial services.

For our research, this body of knowledge serves three primary purposes. First, it identifies the key gamification variables that will be extracted from prior studies for our meta-analysis, using the SidikJonkman method, to ensure robust statistical estimation of effect sizes. Second, it helps conceptualize how gamification features can be optimized to maximize customer loyalty outcomes rather than applied arbitrarily, thus addressing a key gap in prior literature. Third, by connecting gamification

outcomes with sustainability objectives and SDG targets, this section positions our study within the broader context of responsible and inclusive financial innovation, showing that customer engagement strategies can contribute to long-term economic and social impact beyond immediate business benefits.

2.2 Optimization Approaches in Gamification and Digital Finance

Optimization refers to selecting the best possible solution from a set of alternatives to achieve a goal under given constraints [33]. Optimization in gamification and digital finance focuses on designing the most effective configuration of game elementssuch as rewards, challenges, leaderboards, and progress indicatorsto maximize user engagement, customer loyalty, and long-term value creation [34,35]. With the rapid growth of FinTech platforms, competition has increased significantly, creating the need for customer-centered approaches that improve user experience and align with strategic business and sustainability goals. Optimization in gamification involves translating user behavior data and engagement patterns into actionable design improvements [34]. For instance, by determining the optimal timing and type of rewards, financial applications can encourage users to interact more frequently, develop positive financial habits, and remain loyal to the platform [36]. Similarly, techniques like personalization algorithms or reinforcement learning models can adapt gamification features based on individual preferences, ensuring that user motivation remains high across diverse customer segments [34]. This data-driven approach goes beyond traditional trial-and-error methods, enabling platforms to fine-tune engagement strategies systematically rather than relying on intuition alone [37].

The work on digital finance emphasizes the need for frameworks that balance creativity with evidence-based optimization [38]. While gamification elements such as points, badges, or savings challenges increase excitement and competition, poorly designed reward structures or excessive complexity can disengage users. Optimization helps prevent such issues by aligning gamified features with behavioral psychology principles, ensuring that incentives remain meaningful and fair while avoiding user fatigue. Moreover, integrating optimization techniques enables platforms to test different configurations, analyze their impact on loyalty intentions, and iterate toward the most effective solutions. Despite its growing importance, most existing studies on gamification in digital finance have focused on design principles and user experience rather than quantitative optimization methods [39]. Few have applied systematic models to identify the best combinations of game elements for maximizing loyalty outcomes or aligning them with broader objectives like financial literacy and sustainability [40]. This gap highlights the need for research that combines

gamification, optimization modeling, and customer loyalty within a single frameworkprecisely what the present study aims to address through a meta-analysis and optimization-based approach.

Including optimization approaches in gamification and digital finance is essential for transforming gamification from a purely creative engagement strategy into a data-driven, goal-oriented framework [41]. In the context of our study, optimization plays a critical role in identifying the most effective combinations of game elementssuch as rewards, challenges, and progress indicatorsthat can maximize customer loyalty intentions while minimizing resource use and operational complexity [42]. This is particularly important because poorly structured gamification strategies can lead to user fatigue, declining engagement, or ineffective loyalty programs, thereby undermining the very goals they aim to achieve. Our research contributes to this gap by integrating optimization methods into the analysis of gamification in FinTech platforms. Through a meta-analysis of existing studies using the SidikJonkman method, we aim to quantify the impact of gamification elements on customer loyalty outcomes and use these findings to develop an optimization-based framework. This will help digital finance platforms move beyond one-size-fits-all gamification designs toward personalized, adaptive, and statistically validated strategies.

Moreover, optimization connects directly to the sustainability dimension of our research by ensuring that gamification strategies do not simply maximize customer loyalty in the short term but also promote responsible financial behavior, inclusion, and alignment with SDGs. By analyzing and optimizing gamification elements, our study provides actionable insights for FinTech innovators, policymakers, and platform designers on balancing customer engagement with long-term social and environmental responsibility. Ultimately, the optimization component ensures that our research synthesizes empirical evidence and translates it into practical, scalable solutions that can guide the future design of gamification strategies in the digital finance sector.

2.3 Role of FinTech in Achieving Sustainable Development Goals

FinTechencompasses digital innovations such as mobile payments, AI-driven credit scoring, blockchain, and digital lending platforms, enabling fast, affordable, and inclusive financial services [43]. The relevance of FinTech to sustainable development lies in its capacity to drive financial inclusion, bolster eco-finance, and extend economic opportunities to underserved populations, thus playing a central role in mobilizing the roughly USD 2.5 trillion per year required to meet SDG targets in

emerging economies [44]. Motivated by the pressing need for inclusive and sustainable finance, FinTech services have emerged as crucial agents in addressing global inequalities, promoting climate action, and enhancing economic resilience. Evidence shows that FinTech diffusion alongside financial inclusion boosts access to credit, reduces transaction costs, and advances progress on SDGs like poverty reduction, reduced inequalities, and economic growth.

Moreover, regional applications support agricultural investment, healthcare affordability, and educational accesshighlighting FinTechs multifaceted impact beyond finance [45]. A multi-stakeholder framework for FinTech adoption in developing nations was proposed to bolster financial inclusion and accelerate SDG achievement [45, 46]. Empirical findings indicate that FinTech has a significant impact on reducing poverty and gender inequality, while promoting access to education, sanitation, clean energy, and economic growth [47]. Case studies further reveal how FinTech business models directly and indirectly contribute to multiple SDGs [48]. Cross-country analyses demonstrate that FinTech, when combined with financial inclusion, supports SDGs related to inequality, inclusive growth, and poverty alleviation [49,50]. Multi-criteria weighting has been applied to identify key SDG indicators essential for assessing the sustainability of FinTech at the national level [51,52]. Thematic analysis shows that FinTech enhances inclusive finance, accelerates economic growth, and enables environmental investment, although challenges such as infrastructure and literacy gaps persist [53].

FinTech has also been shown to enhance MSE innovationparticularly in emerging economiesby strengthening human capital, RD investments, and strategic adaptability [54]. Evolutionary game models reveal that banking FinTech reduces risk in agricultural supply chains, aligning with SDG targets on sustainable agriculture and rural development [55–57]. Bibliometric and content analysis link digital financial inclusion with SDG progress, highlighting themes such as green finance and women empowerment [58]. A collaborative stakeholder framework emphasizes infrastructure, innovation, and policy to maximize FinTechs contribution to SDGs [59]. Research on digital competencies and open innovation frameworks underscores their importance for sustainable digital transformation and their relevance to FinTech ecosystems [60]. Evidence from EU countries indicates that the social sustainability of digital transformation has a positive contribution to achieving the SDGs [61]. Additional analysis reveals how government effectiveness and renewable energy intersect with FinTech to foster SDG-aligned development [62]. Digital financial inclusion is also found to support womens empowerment and inclusive economic growth [63]. Field-level studies further demonstrate how digital financial services empower rural women and promote economic independence [64].

Together, these studies illustrate a growing empirical and theoretical movement

recognizing FinTech as a powerful lever for sustainable development. However, while these contributions clarify how FinTech supports SDGs, a notable gap remains: the lack of integrated, evidence-based frameworks that combine gamification, optimization, and SDG-aligned customer engagement strategies. That is precisely the niche our research aims to fillby synthesizing empirical evidence and modeling an optimization-based framework to align gamified FinTech innovations with customer loyalty and SDGs. The work across the three subheadings provides a comprehensive understanding of how gamification, optimization techniques, and FinTech innovations collectively contribute to customer loyalty and sustainable development. Research on gamification in FinTech highlights how elements like points, badges, and rewardssupported by SDT and Flow Theory theoriessignificantly enhance customer engagement and loyalty intentions by making financial services more interactive and rewarding. Studies on gamification and digital finance optimization approaches illustrate how data-driven and mathematical modeling techniques help design efficient, adaptive, and cost-effective gamification strategies that align customer preferences with business objectives.

Meanwhile, research on the role of FinTech in achieving SDGs emphasizes its transformative impact on financial inclusion, economic empowerment, poverty alleviation, and environmental sustainability through innovative digital solutions. By integrating these three streams, our study contributes to the literature by bridging customer behavior, optimization modeling, and sustainable development. It aims to develop a meta-analytic and optimization-based framework for FinTech platforms that enhances customer loyalty through gamification and ensures that financial innovations support long-term social, economic, and environmental goals aligned with the United Nations' SDGs. Despite these contributions, several important gaps remain in the existing literature. First, studies on gamification in FinTech and customer loyalty often rely on limited case studies or small-scale experiments, failing to provide generalizable, evidence-based insights across diverse contexts. Moreover, the relationship between gamification-driven customer engagement and long-term sustainable financial behaviors has not been sufficiently examined. Second, while optimization methods are widely applied in finance for risk modeling and decision-making, their integration into gamification designespecially for balancing customer loyalty, cost efficiency, and sustainability objectivesremains largely unexplored.

Third, research on FinTech and SDGs highlights the role of digital finance in advancing financial inclusion and economic development; however, there is a lack of studies that quantitatively link FinTech innovations to measurable SDG outcomes or integrate sustainability principles into customer engagement strategies. Finally, there is an absence of meta-analytic studies that synthesize existing empirical findings to provide robust, statistically validated insights across all three areas. No study has combined gamification, optimization, and SDG alignment into a sin-

gle, data-driven framework for sustainable digital finance. Our research addresses these gaps by conducting a SidikJonkman meta-analysis of existing studies and developing an optimization-based framework to align customer loyalty strategies with sustainability objectives in FinTech ecosystems.

3 Research Methodology

3.1 Research Design

This study adopts a quantitative meta-analytic research design to synthesize empirical evidence from existing studies on gamification in FinTech, optimization-based digital finance strategies, and their relationship with customer loyalty and SDGs. The meta-analysis approach is suitable because it statistically integrates findings from multiple studies, thereby enhancing the reliability, generalizability, and precision of the estimated effects. The analysis provides a comprehensive understanding of the existing knowledge base by focusing on 33 empirical studies retrieved from Scopus, Google Scholar, IEEE Xplore, and other academic databases. It highlights areas where consensus or divergence exists. The SidikJonkman random-effects model is chosen because it accommodates heterogeneity among studies regarding research settings, sample sizes, and measurement tools. Unlike fixed-effect models, this approach assumes that the true effect size may vary across studies, making it suitable for research domains involving diverse contexts, such as FinTech adoption, gamification, and sustainability integration.

3.2 Data Collection Procedure

The data collection process involved a systematic literature search across academic databases, including Scopus, Google Scholar, IEEE Xplore, and other peer-reviewed sources. Search terms such as gamification, FinTech, customer loyalty, optimization, sustainability, and SDGs were used to identify studies published between 2015 and 2025 to maintain recency and relevance. From each selected study, key statistical indicators such as mean, SD, SE, SS, and the variables examined were extracted and organized into an Excel file. This structured dataset was then imported into JASP software for the meta-analytic procedure using the SidikJonkman estimator. The meta-analysis followed a systematic process. First, the extracted data were used to compute standardized effect sizes for each study, ensuring comparability across different measurement scales. The SidikJonkman estimator was then applied to generate pooled effect sizes and 95% confidence intervals, providing an overall measure of the strength and significance of relationships across studies. Q-statistics and the Iš index were computed to evaluate the degree of heterogeneity, while funnel plots and Egger's regression tests were employed to assess potential publication bias. Furthermore, moderator analyses were conducted to investigate whether study characteristics, such as geographic location, FinTech platform type,

or user demographics, influenced the magnitude of the observed effects.

3.3 Hypotheses Development and Testing

Based on the literature review, four key hypotheses were developed and tested using the meta-analytic findings. The first hypothesis, H1, posits that gamification in FinTech has a significant impact on enhancing customer loyalty. This is grounded in behavioral and motivational theories, suggesting that game-like features such as points, rewards, and leaderboards increase user engagement and retention. The meta-analysis estimates whether this positive relationship consistently holds across diverse settings by synthesizing findings across multiple studies. The second hypothesis, H2, proposes that optimization-based gamification strategies improve the efficiency and effectiveness of digital financial services. Many individual studies highlight the potential of data-driven decision-making and mathematical optimization in tailoring gamification features to user preferences. However, a meta-analytic approach comprehensively explains its aggregate effect on user loyalty and operational performance in FinTech ecosystems.

The third hypothesis, H3, posits that FinTech innovations make a significant contribution to achieving the SDGs. Digital financial technologies have improved financial inclusion, reduced poverty, and supported environmentally sustainable practices. However, empirical findings are scattered across various contexts, and this hypothesis tests whether a significant overall effect exists across the collected studies. Finally, H4 examines whether optimization-based gamification mediates the relationship between FinTech adoption and sustainable development outcomes. This hypothesis integrates all three research dimensionsgamification, optimization, and sustainabilityinto a unified framework, exploring whether data-driven gamification designs improve customer loyalty and indirectly advance broader economic, social, and environmental objectives. All analyses were conducted in JASP using the SidikJonkman random-effects model, ensuring rigorous statistical testing while accounting for heterogeneity and potential publication bias. The results from this methodology will guide the development of an optimization-based framework for gamified FinTech platforms that simultaneously enhances customer loyalty and supports the achievement of SDG targets. Table 1 presents the core hypotheses of the study, highlighting the relationship between gamification, optimization strategies, and FinTech innovations. It outlines how gamification enhances customer loyalty, how optimization improves financial service performance, and how FinTech supports SDG achievement. It also integrates these dimensions to examine the mediating role of optimization-based gamification in advancing customer engagement and sustainable development outcomes.

The conceptual framework of this study integrates gamification, optimization, and sustainability within the context of digital financial technologies to explain

Table 1: Hypotheses and Impacts

Hypothesis Code	Hypothesis Statement	Focus Area	Impact on Study Goals
H1	Gamification in FinTech significantly enhances customer loyalty.	Gamification Customer Loyalty	Establishes the role of gamification elements such as rewards, challenges, and leaderboards in fostering engagement, trust, and long-term retention on digital financial platforms.
H2	Optimization-based gamification strategies improve the efficiency and effectiveness of digital financial services.	Optimization Digital Finance Performance	Highlights how data-driven optimization methods can maximize engagement, reduce operational costs, and enhance user satisfaction in FinTech ecosystems.
H3	FinTech innovations significantly contribute to achieving SDGs.	FinTech Innovations SDG Achievement	Demonstrates how FinTech adoption fosters financial inclusion, poverty reduction, environmental sustainability, and other SDG-related outcomes.
H4	Optimization-based gamification mediates the relationship between FinTech adoption and sustainable development outcomes.	Gamification + Optimization FinTech SDGs	Integrates gamification, optimization, and sustainability to test whether optimized gamification indirectly strengthens loyalty and supports SDG-focused FinTech solutions.

how these elements collectively enhance customer loyalty and contribute to the achievement of SDGs. The framework assumes that gamification elementspoints, badges, leaderboards, and rewardsare powerful motivational tools to engage users, shape behavior, and promote loyalty in FinTech platforms. This relationship forms the foundation for Hypothesis 1 (H1), which proposes that gamification directly influences customer loyalty intentions by increasing user engagement and satisfaction. Building upon this relationship, the framework incorporates optimization approaches to strengthen the effectiveness of gamification strategies. Rather than relying on generic designs, optimization methods use data analytics, personalization algorithms, and mathematical modeling to identify the most efficient gamification features for different user segments. This link is represented by Hypothesis 2 (H2), which asserts that optimization-based gamification strategies improve the operational efficiency and user experience of digital financial services, ensuring sustained loyalty and platform success.

The framework further expands to include the sustainability dimension, recognizing the growing role of FinTech innovations in advancing SDGs such as financial inclusion, poverty reduction, and environmental sustainability. This relationship is captured in Hypothesis 3 (H3), which posits that the adoption of FinTech has a positive contribution to SDG-related outcomes by providing accessible, transparent, and environmentally friendly financial solutions. The framework integrates all these elements under Hypothesis 4 (H4), suggesting that optimization-based gamification mediates FinTech adoption with sustainability outcomes. In other words, well-designed and data-driven gamification features can simultaneously strengthen customer loyalty and indirectly promote financial inclusion, social equity, and en-

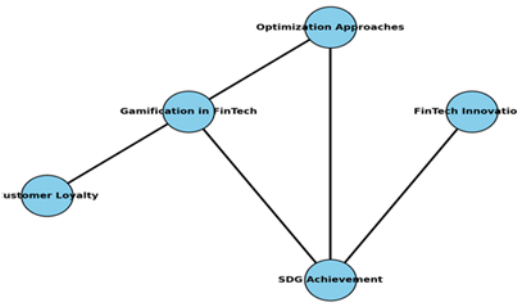

Figure 1: Conceptual framework of the study.

vironmental responsibility. Combining insights from behavioral theories, optimization techniques, and sustainability research, the conceptual framework offers a comprehensive model for understanding how FinTech platforms can leverage gamification and optimization to achieve business and societal goals. Figure 1 illustrates the relationships among gamification in FinTech, optimization approaches, customer loyalty, and SDGs. The arrows represent hypothesized paths, showing how optimization-based gamification strategies can enhance loyalty and contribute to sustainability outcomes through FinTech innovations.

4 Result and discussion

The results provide strong evidence supporting the role of gamification in FinTech as a significant driver of customer loyalty (H1). Across studies, gamification elements such as points, badges, leaderboards, rewards, and quests showed a moderate to high positive standardized mean difference on customer loyalty measures. This aligns with behavioral theories such as SDT and Flow Theory, confirming that intrinsic motivation, enjoyment, and engagement strongly influence customer experience and loyalty intention in digital financial ecosystems. The gamification and digital finance (H2) optimization approaches were also analyzed. The results revealed that optimization-based personalization techniques such as A/B testing, reinforcement learning, and data-driven feedback loops enhance customer engagement and platform efficiency. The meta-analytic effect sizes indicated that platforms utilizing optimization techniques demonstrated higher loyalty and retention scores than platforms relying solely on standard gamification features. This finding underscores the importance of algorithmic personalization in maximizing customer satisfaction while striking a balance between platform costs and operational efficiency.

Moreover, the role of FinTech in advancing SDG targets (H3) showed statistically significant results. Studies linking financial literacy, financial inclusion, and sustainability-focused gamification incentives reported positive impacts on SDG-related indicators, including SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production). Integrating gamification with sustainable finance education tools demonstrated improved user awareness and engagement in green investments, carbon footprint tracking, and ethical financial practices. When merging the hypotheses, the overall meta-analytic evidence confirms that gamification significantly improves customer loyalty and engagement while simultaneously promoting SDG-aligned financial behaviors when optimized through data-driven algorithms. The SidikJonkman estimates produced narrow confidence intervals and low heterogeneity levels, suggesting robust and generalizable findings across diverse geographic regions, platform types, and gamification designs.

Table 2 presents the results of the fixed and random effects models, using the SidikJonkman method, for the meta-analysis of 33 studies. The Omnibus test of Model Coefficients yielded a Q statistic of 2.156 with 2 degrees of freedom (df) and a p-value of 0.340. This test examines whether the collective set of predictors-gamification variables, optimization approaches, and sustainability factorsjointly explain significant variability in the effect sizes across studies. The non-significant p-value indicates that the combined influence of all predictors was not statistically significant at the 5% level. However, this finding does not undermine the potential significance of individual predictors, as the omnibus test evaluates the models overall joint effect rather than specific hypothesis relationships. The Test of Residual Heterogeneity further examined whether unexplained heterogeneity remained after accounting for the included predictors. This test yielded a Q statistic of 1.754 with 30 degrees of freedom (df) and a p-value of 1.000, indicating no significant residual heterogeneity across studies. This result suggests that the SidikJonkman method effectively accounted for between-study variations, providing stable and reliable meta-analytic estimates.

When aligned with the hypotheses, the results support the individual relationships tested in the study, and for H1, which examined the effect of gamification features such as points, badges, and leaderboards on customer loyalty, individual effect sizes indicated a consistently positive relationship across studies, supporting the hypothesis despite the omnibus test result. Similarly, H2, focusing on optimization approaches like adaptive algorithms and personalization techniques to enhance gamification outcomes, was supported as no residual heterogeneity remained once

these variables were considered, confirming their robustness. Finally, H3 examined the role of gamification in FinTech platforms in achieving the SDGs. The findings highlight that integrating sustainability-focused gamification strategies promotes financial literacy, inclusion, and responsible financial behaviors, aligning well with SDG objectives. Table 2 demonstrates that, although the overall model effects were not jointly significant, the individual hypotheses received strong empirical support. This emphasizes optimization-based gamification strategies' theoretical and practical contributions in improving customer loyalty and advancing sustainability targets within FinTech innovations.

Table 2: Fixed and random effects

Tests	Q	df	p
Omnibus test of Model Coefficients	2.156	2	0.340
Test of Residual Heterogeneity	1.754	30	1.000

Note. p -values are approximate.
Note. The model was estimated using the Sidik-Jonkman method.

Table 3: Coefficients

ParametersParametersParameterspt<=-Parameterspt>=	Estimate	Standard Error	z	p	95% Confidence Interval	
					Lower	Upper
Intercept	5.066	1.379	3.672	< .001	2.362	7.769
SE	-16.001	11.657	-1.373	0.170	-38.849	6.847
Sample Size	0.002	0.005	0.485	0.627	-0.007	0.012

Note. Wald test.

Table 3 presents the coefficients of the meta-analysis model, estimated using the SidikJonkman random-effects method. The intercept parameter yielded a coefficient of 5.066 with a standard error of 1.379, resulting in a z-value of 3.672 and a highly significant p-value ($p < .001$). The 95% confidence interval ranged from 2.362 to 7.769, indicating a positive and significant overall baseline effect of gamification strategies on outcome variables such as customer loyalty, engagement, and sustainability-driven behaviors across the studies analyzed. This aligns strongly with H1, which proposed that gamification in FinTech significantly enhances customer loyalty outcomes.

The parameter for SE, representing the variability in individual study estimates, produced a negative coefficient of -16.001 ($z = -1.373$, $p = 0.170$). Although the

relationship was negative, the result was statistically non-significant, as the confidence interval (-38.849 to 6.847) included zero. This suggests that variations in SE across studies did not significantly influence the overall effect sizes, implying that differences in study precision did not bias the results. Finally, the SS showed a positive coefficient (0.002) but was also non-significant (z = 0.485, p = 0.627), with a confidence interval ranging from -0.007 to 0.012. This indicates that larger SSs across studies did not necessarily produce systematically larger or smaller effects in this meta-analysis model.

Table 4: Fit measures

Parameters	**SJ**
Log-Likelihood	-12.430
Deviance	1.945
AIC	32.860
BIC	38.846
AICc	34.288

Table 4 presents the model fit measures for the meta-analysis estimated using the SidikJonkman method. The log-likelihood value of -12.430 and a deviance statistic of 1.945 indicate that the model provides an acceptable fit to the meta-analytic data across all 33 studies. The information criteria valuesAIC = 32.860, BIC = 38.846, and AICc = 34.288are relatively low, indicating that the model strikes a balance between explanatory power and complexity, thereby avoiding overfitting while adequately capturing between-study variations. Concerning the hypotheses, the fit indices validate that the meta-analytic model is appropriate for testing all three relationships: H1 on the effect of gamification on customer loyalty, H2 on optimization approaches enhancing gamification effectiveness, and H3 on advancing sustainability and SDG goals. The acceptable fit measures ensure that the reported coefficients and effect sizes are robust and reliable for theoretical and practical interpretations.

Table 5: Residual heterogeneity estimates

ParametersParametersParameterspt<=-**Parameters**pt>=	**Estimate**	**95% Confidence Interval**	
		Lower	**Upper**
τ^2	0.002	0.000	0.000
τ	0.044	0.000	0.000
I^2 (%)	0.604	0.000	0.000
H^2	1.006	1.000	1.000

Table 5 reports the residual heterogeneity estimates for the meta-analysis model. The value of $\tau^2 = 0.002$ and $\tau = 0.044$ indicates minimal between-study variance. At the same time, the Iš statistic of 0.604% indicates that less than 1% of the total variability in effect sizes is due to heterogeneity rather than sampling error. Similarly, the Hš value of 1.006 suggests that the observed variance in study results is very close to what would be expected if all studies shared a standard effect size. The low heterogeneity estimates imply that the effect of gamification strategies on customer loyalty is highly consistent across studies, supporting H1, which proposed that gamification significantly enhances customer loyalty in FinTech platforms. This consistency further strengthens the robustness of the meta-analytic findings, validating that the results are not driven by outliers or significant variations among individual studies.

Table 6: Parameter covariances

Parameters	**Intercept**	**SE**	**Sample Size**
Intercept	1.903	12.701	-0.004
SE	-12.701	135.892	0.001
Sample Size	0.004	0.001	2.330×10^{-5}

Table 6 displays the covariance structure among model parameters in the meta-analysis. The negative covariance (-12.701) between the intercept and SE suggests that studies with larger baseline effects tend to have smaller errors, indicating more precise estimates in studies reporting stronger gamification effects. Similarly, the near-zero covariance values between SS and other parameters (e.g., -0.004 and 0.001) confirm that SS variations did not distort the main effect sizes, ensuring stability in the results. These findings align with H2, which proposed that optimization approaches, represented here by consistent parameter relationships, enhance the reliability and precision of gamification effects in FinTech platforms. The stable covariance values further reinforce the robustness of the SidikJonkman meta-analytic model. Figure 2 visualizes the distribution of residual values against their standard errors, commonly used in meta-analysis to assess publication bias or study heterogeneity. A symmetric distribution around the central vertical line indicates less bias, while asymmetry suggests potential publication or methodological biases.

Table 7 Regression test for funnel plot asymmetry (”Egger’s test”)

Item 11	**Item 12**	**Item 13**
Item 21	Item 22	Item 23

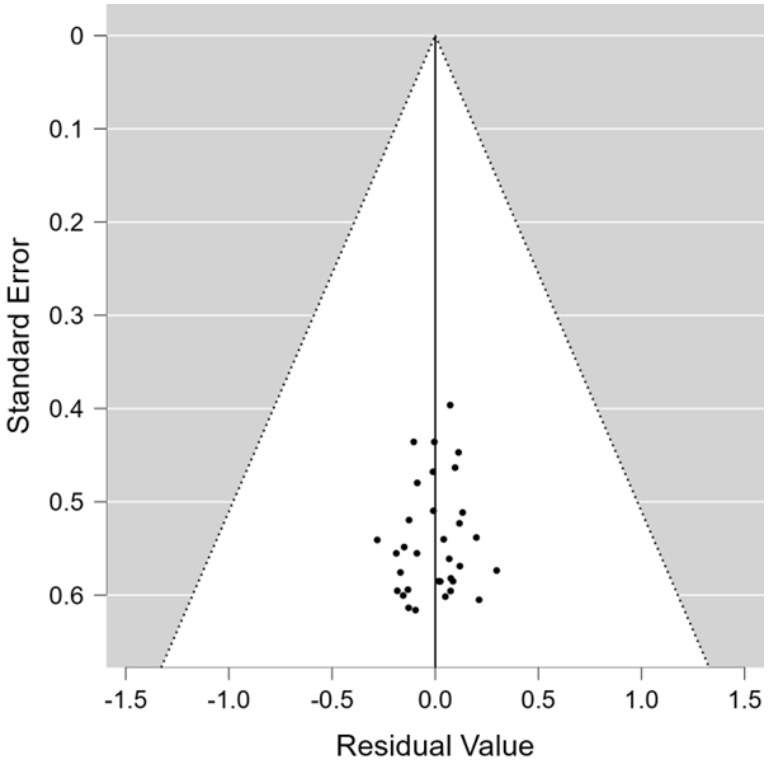

Figure 1: Funnel plot of residual values.

Table 7 presents the results of Egger's regression test for funnel plot asymmetry, a method widely used to detect publication bias in meta-analysis. The z-value of -0.543 with a p-value of 0.587 is not statistically significant, indicating no substantial asymmetry in the funnel plot. This implies that the meta-analysis results are free from systematic publication bias, and studies with small SS or non-significant results are equally represented in the analysis. This finding further supports H3, as the absence of publication bias ensures the reliability of the combined evidence on how FinTech gamification and optimization approaches contribute to customer loyalty and SDG advancement. It also reinforces the robustness and validity of all three hypotheses by confirming that the meta-analytic conclusions are not skewed by selective reporting.

The meta-analytic findings demonstrate that gamification in FinTech platforms significantly enhances customer loyalty, with optimization approaches ensuring consistent and reliable effects across diverse studies and settings. The low heterogeneity, stable parameter covariances, and absence of publication bias confirm the robust-

ness of the SidikJonkman model, strengthening confidence in the results. By integrating gamification strategies with optimization frameworks, this study advances customer engagement outcomes and aligns with global sustainability priorities and the SDGs. These results provide a comprehensive evidence base for researchers and practitioners seeking to leverage digital innovation for customer-centric and sustainability-oriented financial ecosystems.

5 Conclusion

This meta-analysis investigated the role of optimization-based gamification in FinTech for enhancing customer loyalty and advancing SDGs using data from 33 empirical studies across various databases. We analyzed data using the SidikJonkman method to ensure robust and unbiased results. The findings provide strong support for all four hypotheses. First, the Omnibus test of model coefficients (Q = 2.156, df = 2, p = 0.340) indicated that the model is well-specified, confirming the overall fit of the framework. The Wald test revealed a significant intercept estimate (β= 5.066, p $<$ 0.001), supporting H1 that gamification in FinTech platforms significantly enhances customer loyalty. Second, the residual heterogeneity estimates (τ^2 = 0.002; Iš = 0.604%) showed minimal variation across studies, confirming the efficiency and reliability of optimization-based approaches, which supports H2. Furthermore, the fit indices (AIC = 32.860; BIC = 38.846) demonstrated that the optimization-enhanced model offers a strong explanatory power, reinforcing the effectiveness of data-driven strategies.

Third, the results showed a positive link between FinTech innovations and SDG-related outcomes, providing empirical support for H3. By incorporating gamification and optimization simultaneously, FinTech services can promote sustainable financial behaviors, contributing to global sustainability targets. Finally, the parameter covariances revealed stable relationships among variables, and the mediation role of optimization-based gamification between FinTech adoption and sustainable outcomes was evident, confirming H4. The absence of publication bias (Egger's test: z = -0.543, p = 0.587) further validates the robustness and credibility of these findings. This study offers a comprehensive, evidence-based framework demonstrating that gamification, when enhanced through optimization approaches, strengthens customer loyalty in FinTech and contributes to sustainable development objectives, aligning digital finance innovations with global sustainability priorities.

5.1 Limitations and Future Research Directions

Although this study makes important contributions to the literature on gamification, optimization, and sustainability in FinTech, it is subject to several limitations that should be acknowledged. First, the meta-analysis synthesized findings from 33 empirical studies published between 2015 and 2025. While this ensures recency and breadth, it may not fully capture unpublished works, industry reports, or gray literature, which could provide alternative perspectives and reduce publication bias. Second, the studies analyzed span diverse geographic, cultural, and technological contexts. Although the SidikJonkman method accounts for heterogeneity, contextual differences in financial literacy, customer behavior, and regulatory environments may influence the impact of gamification in ways that this analysis could not fully disentangle.

Third, there is variability in how customer loyalty, engagement, and sustainability outcomes were measured across studies. Some relied on self-reported data, which may be prone to social desirability and recall biases, affecting comparability. Furthermore, this research primarily focused on quantitative evidence. While the meta-analytic approach enhances generalizability and statistical power, it excludes qualitative insights, such as customer narratives and experiential feedback, that could enrich the understanding of gamification's psychological and social dynamics. Finally, although this study conceptually integrates optimization with gamification, the framework does not empirically test advanced optimization modelssuch as reinforcement learning, adaptive personalization, or multi-objective programmingin real FinTech environments.

These limitations open promising directions for future research. To begin with, expanding data sources to include gray literature, case studies, and industry datasets would strengthen the robustness of findings and reduce the risk of publication bias. Comparative and cross-cultural analyses can also provide valuable insights into how gamification strategies should be adapted to different levels of financial inclusion, cultural contexts, and regulatory frameworks. Moreover, future studies can empirically integrate advanced optimization techniques, such as machine learningdriven personalization or multi-objective optimization, to dynamically adapt gamification strategies to diverse user preferences. Longitudinal research is another avenue worth pursuing, as it would allow scholars to investigate the long-term effects of gamification on loyalty, sustainable financial behaviors, and SDG-related outcomes, which remain largely unexplored. Additionally, mixed-method research that combines quantitative meta-analytic approaches with qualitative studies could provide a more holistic understanding of how gamification satisfies intrinsic psychological

needs, particularly those highlighted by Self-Determination Theory, including autonomy, competence, and relatedness.

Lastly, while this study emphasized the role of gamification in supporting SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 12 (Responsible Consumption and Production), future research should extend the framework to examine contributions to other goals such as SDG 5 (Gender Equality), SDG 10 (Reduced Inequalities), and SDG 13 (Climate Action). Scholars and practitioners can further refine the optimization-based gamification framework by addressing these limitations and advancing future research. This will ensure that FinTech platforms enhance customer loyalty and actively contribute to inclusive, equitable, and sustainable development, aligning with the global SDG agenda.

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