Communication

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FinTech and AI as Opportunities for a Sustainable Economy

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Abstract: The need for a sustainable economy has grown as technological advancements increasingly influence economic and social structures. This study investigates the role of FinTech and artificial intelligence (AI) in fostering sustainable development by facilitating green initiatives and promoting social responsibility. The research hypothesis posits that FinTech enables better access to financing for economic and social development projects, while AI enhances decision-making processes critical to the implementation of these initiatives. Through a qualitative approach, the study analyzes the interactions between FinTech, AI, and the Sustainable Development Goals (SDGs), exploring whether their relationship is bilateral or unidirectional. The findings suggest that both technologies play a significant role in supporting sustainability, with FinTech providing the necessary financial tools and AI optimizing decision-making. Furthermore, the study identifies barriers, such as regulatory challenges and technological gaps, that hinder the full integration of these technologies into sustainable development practices. It also highlights facilitators, such as policy support and technological innovation, that accelerate their adoption. The conclusions emphasize the transformative potential of FinTech and AI in achieving robust economic growth, reducing inequalities, and fostering a new cultural approach to resource management and societal responsibility.

Keywords: FinTech; artificial intelligence; sustainable development; green economy; financial inclusion; social responsibility; technological innovation; SDGs

JEL Classification: O33; G23; Q56; O44.

1. Introduction

The global transition toward a sustainable economy has become one of the most pressing challenges of the 21st century. Sustainable development, as defined by the United Nations, is the process of meeting present needs without compromising the ability of future generations to meet their own needs. This requires a comprehensive approach, addressing environmental, economic, and social dimensions. Technological innovations, particularly in financial technology (FinTech) and artificial intelligence (AI), have emerged as significant enablers of this transition. These technologies hold the potential to reshape financial systems, drive the green economy, and enhance decision-making for sustainable development [1,2].

In recent years, FinTech has revolutionized access to financing, enabling underserved populations and businesses to obtain capital, thereby fostering economic inclusion and supporting social development. Moreover, FinTech platforms are increasingly facilitating investment in green projects, offering new financial instruments for environmental sustainability [3]. Meanwhile, AI has transformed decision-making processes across various sectors by improving efficiency, reducing waste, and optimizing resource use [4]. Despite their individual successes, the integration of these technologies into sustainable development practices is still a relatively underexplored area, with gaps in research on their combined impact and interaction.

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Several studies have addressed the individual contributions of FinTech and AI to sustainable development. Some argue that FinTech's role in financing sustainable projects directly contributes to achieving the United Nations' Sustainable Development Goals (SDGs), especially in low-income countries [5,6]. On the other hand, AI is seen as a powerful tool for enhancing the management of resources and decision-making for sustainable development [7,8]. However, the exact nature of the relationship between these technologies and the SDGs is still debated, with some scholars suggesting that their impacts are bilateral, while others propose a more unidirectional relationship [9,10].

This study aims to explore how FinTech and AI can support sustainable economic development by advancing green initiatives and fostering social responsibility. It investigates the barriers hindering their full integration and examines the facilitators that could accelerate their deployment in sustainability efforts. By addressing these issues, the research contributes to understanding the potential synergy between FinTech and AI in advancing the SDGs and creating a more resilient and equitable global economy.

Literature Review

The exploration of how FinTech and artificial intelligence (AI) contribute to sustainable economic development is a rapidly expanding field of research, driven by the pressing need for innovative solutions to achieve the United Nations' Sustainable Development Goals (SDGs). While numerous studies have investigated the individual impacts of FinTech and AI, their combined role in advancing sustainability remains relatively underexplored. This section reviews the current state of the literature, focusing on the contributions of FinTech and AI to sustainable development, the challenges they face, and the potential for synergy between these technologies.

FinTech and Sustainable Development

FinTech has emerged as a transformative force in financial services, particularly in providing access to financing for underserved populations and businesses. Research has highlighted the significant role of FinTech in fostering financial inclusion, particularly in developing economies where traditional banking systems are often inaccessible [5]. By leveraging mobile technology and digital platforms, FinTech has made it possible for individuals and businesses in low-income regions to access capital, thereby enabling their participation in economic development activities. Furthermore, FinTech is increasingly facilitating investment in green projects and sustainable initiatives. Platforms such as green bonds and impact investing have become more accessible through FinTech, directing capital toward environmentally responsible businesses and projects [6]. Zhao and Wang (2020) argue that the integration of FinTech with sustainable development principles can drive the transition to a green economy, fostering innovation in clean technologies and environmentally friendly practices.

However, the full potential of FinTech in sustainable development is hindered by barriers such as regulatory challenges, technological gaps, and financial literacy [7]. Researchers like Garcia and Thomas (2018) emphasized the need for comprehensive regulatory frameworks that enable the scaling of FinTech solutions while ensuring consumer protection and financial stability. Moreover, there are concerns about the potential for digital financial exclusion, where certain populations may be left behind due to lack of access to the necessary technology [8].

Artificial Intelligence and Sustainable Development

AI, as a tool for optimizing decision-making processes, holds great promise for advancing sustainability. AI can enhance the management of resources, reduce inefficiencies, and improve the allocation of financial and environmental resources. For example, AI is increasingly being used in agriculture to optimize water usage, predict crop yields, and reduce waste through precision farming technologies [9]. In the energy sector, AI has been applied to optimize energy consumption, predict demand, and integrate renewable energy sources into grids more efficiently. Researchers such as Kumar (2020) have pointed out that AI's ability to process vast amounts of data and identify patterns makes it an essential tool for achieving the SDGs, particularly in resource management and climate change mitigation.

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Moreover, AI is playing a critical role in decision-making processes related to sustainable development. AI algorithms can analyze large datasets and provide insights that are difficult for humans to identify, leading to more informed decisions about sustainable practices and policies [10]. For instance, AI has been used in disaster response management to predict the impact of natural disasters and guide the allocation of resources to the most affected areas, improving resilience in vulnerable communities.

Despite its potential, the use of AI in sustainable development is not without challenges. Ethical concerns, such as bias in AI algorithms and the environmental impact of AI infrastructure (e.g., energy consumption of data centers), remain significant barriers. Schmidt and Miller (2019) argue that addressing these ethical issues is crucial to ensuring that AI contributes positively to sustainable development.

The Synergy Between FinTech and AI

While FinTech and AI have been studied individually in the context of sustainable development, their synergy has received less attention. There is growing recognition that the combination of these technologies can unlock new opportunities for achieving sustainability. FinTech can leverage AI to enhance its services, offering more personalized financial products, improving risk assessments, and enabling better decision-making processes for sustainable investments. On the other hand, AI can benefit from the vast amounts of data generated by FinTech platforms to improve the accuracy of its predictions and optimize resource management [11].

Patel (2020) explores the potential for a bilateral relationship between FinTech and AI, arguing that the integration of both technologies could accelerate progress toward the SDGs by creating a more efficient, transparent, and accessible financial system. For example, FinTech platforms powered by AI can more effectively match sustainable projects with investors, ensuring that capital flows to the most impactful initiatives. This mutual reinforcement between FinTech and AI can contribute to the achievement of economic, social, and environmental sustainability.

However, several barriers must be overcome to fully realize the potential of this synergy. Regulatory hurdles, the need for interoperability between FinTech platforms and AI systems, and the lack of technological infrastructure in developing regions are among the key challenges highlighted in literature. Green finance frameworks, AI governance, and collaboration between the public and private sectors are critical to overcoming these obstacles [12].

The literature demonstrates the substantial contributions of FinTech and AI to sustainable development. FinTech has revolutionized access to financing and is increasingly supporting sustainable investments, while AI is enhancing decision-making in resource management and policy design. Despite the potential of these technologies, challenges such as regulatory frameworks, technological gaps, and ethical concerns must be addressed to unlock their full potential. The synergy between FinTech and AI presents a promising avenue for advancing the SDGs, but further research is needed to understand the dynamics of their integration and the barriers to achieving their combined impact. The intersection of FinTech, artificial intelligence (AI), and sustainable development has garnered significant academic attention in recent years. While the potential of these technologies to support sustainability is widely acknowledged, the literature highlights several barriers to their successful integration, as well as facilitators that can accelerate their adoption in sustainable development initiatives. This section expands on these barriers and facilitators, addressing challenges such as technological transfer costs, financial inclusion, and social responsibility, as well as discussing key enablers such as Industry 4.0 and Total Quality Management (TQM) mechanisms.

Barriers to Sustainable Development Integration

Cost of Technological Transfer

The cost associated with transferring advanced technologies, including FinTech and AI, to developing countries remains a significant barrier to their widespread adoption. The initial investment required to implement these technologies, coupled with ongoing maintenance and support costs, can be prohibitive for many businesses and governments in low- and middle-income

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countries. This is particularly problematic in the context of sustainable development, where resource allocation is already constrained by competing priorities. Zhao and Wang (2020) [14] note that technological transfer is often hindered by high infrastructure costs, exacerbating the digital divide and slowing down the implementation of green projects in underdeveloped regions.

Financial Inclusion and Confidence in New Financial Products

Financial inclusion is another major challenge in the adoption of FinTech. Many populations, particularly in rural and low-income areas, are hesitant to use digital financial services due to a lack of confidence in new financial products and low levels of financial literacy. Studies indicate that people in underserved areas often lack the trust needed to engage with digital platforms, which limits the potential for FinTech to empower these communities [16,17]. Furthermore, a lack of financial education and awareness about how these products work inhibits their uptake, leading to missed opportunities for financing sustainable initiatives in developing economies [19].

Communication Networks and Access to Financing

The lack of robust communication networks, especially in rural and remote areas, represents a critical barrier to the successful implementation of FinTech and AI-driven solutions. Poor internet connectivity and limited access to mobile technologies in these regions impede individuals and businesses from fully engaging with digital financial services [18]. As FinTech solutions depend heavily on internet infrastructure, those without reliable connectivity remain excluded from participating in the green economy. Moreover, limited access to financing and the absence of banking facilities in these areas further exacerbates the situation, reinforcing economic inequality [17].

Development Gaps: Income Levels and Rural-Urban Differences

Income disparities and rural-urban differences contribute significantly to the challenges of implementing sustainable development solutions. Low-income populations, particularly in rural areas, often face barriers to accessing both traditional financial services and newer FinTech platforms. Kumar (2020) [15]. discusses how the digital divide, characterized by income inequality and disparities in access to education and technology, prevents the equitable distribution of the benefits of FinTech and AI. These gaps also manifest in the lower rates of adoption of sustainable technologies in rural areas compared to urban centers.

Social Responsibility of Institutions in the Banking System

The banking system's social responsibility plays a pivotal role in facilitating or hindering access to financing. Discrimination in access to credit, based on factors such as institutional efficiency or perceived market risk, remains a significant issue. For example, small loans often come with higher interest rates due to the high cost of managing such loans. Furthermore, discriminatory practices based on geographical location or market risks such as varying interest rates for the same product in different countries—pose additional barriers to financial inclusion [20,21]. Addressing these issues requires regulatory reforms that promote equitable access to financial services, particularly for marginalized populations.

Limited Recognition of Basic Science and Insufficient Investment

The insufficient recognition of the importance of basic science and technology development also hampers the potential for FinTech and AI to contribute to sustainable development. Low levels of investment in scientific research and development (R&D) in many developing countries have led to a slow pace of technological innovation and implementation. Furthermore, the failure to balance and complement different SDGs can hinder the effective integration of FinTech and AI into sustainability efforts [22]. Achieving synergies between these technologies and the SDGs requires a holistic approach that integrates technological innovation with social and economic considerations.

Low Financial Literacy and Limited Banking Facilities in Rural Areas

Low financial literacy and the scarcity of banking facilities in rural areas are central barriers to FinTech adoption. As FinTech platforms typically require users to understand digital tools, lack of literacy in financial products and services hinders their use in underbanked regions. Moreover, rural areas often lack physical banking institutions, further limiting access to essential financial services [19,23].

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Facilitators for Advancing Sustainability

While barriers to integrating FinTech and AI into sustainable development are substantial, several facilitators can accelerate their adoption.

Industry 4.0

The rise of Industry 4.0, characterized by the integration of advanced technologies such as AI, the Internet of Things (IoT), and robotics, presents significant opportunities for the adoption of sustainable development practices. Industry 4.0 technologies can drive efficiency, reduce waste, and optimize resource use, making them essential for achieving sustainability goals. Kumar (2020) highlights the role of AI in Industry 4.0, particularly in optimizing resource management and supporting environmentally friendly practices. By promoting green innovation and improving the efficiency of industrial processes, Industry 4.0 can contribute to a sustainable economic transition.

Total Quality Management (TQM) Mechanisms

The adoption of Total Quality Management (TQM) mechanisms can play a crucial role in advancing sustainability through FinTech and AI. TQM emphasizes continuous improvement, customer satisfaction, and efficiency, principles that align well with the objectives of sustainable development. By applying TQM principles to the design and implementation of FinTech solutions, organizations can improve the quality of financial products and services, ensuring that they meet the needs of underserved populations while supporting green projects and social responsibility [24]. Additionally, TQM mechanisms can facilitate better decision-making processes, making it easier to align business objectives with sustainable practices.

The literature reveals a complex landscape of challenges and opportunities in the integration of FinTech and AI into sustainable development. While significant barriers, including the cost of technological transfer, low financial literacy, and social responsibility issues within the banking system, remain, facilitators such as Industry 4.0 and TQM mechanisms offer promising pathways forward. Addressing these barriers and leveraging these facilitators will be critical for realizing the full potential of FinTech and AI in promoting a sustainable and inclusive global economy.

2. Materials and Methods

This section describes the materials and methods employed to investigate the factors influencing the holding of bank accounts by European citizens in the post-pandemic period, using data from the Global Findex database. The analysis is focused on the pre-pandemic, during-pandemic, and post-pandemic periods, and aims to examine the potential impact of factors such as gender, age, education, income, area of residence, and employment status on financial inclusion.

Data Source

The primary data source for this analysis is the Global Findex database, which provides detailed information on financial inclusion, including data on bank account ownership across different demographics and regions. The Global Findex database is publicly available and offers a comprehensive overview of financial behaviors and access to financial services globally, covering key variables such as gender, age, income levels, education, and geographic location. Data from the Global Findex is available for the periods before, during, and after the pandemic, which allows for an analysis of changes over time in the context of financial inclusion.

Study Period

The data analyzed covers three distinct periods:

Pre-pandemic Period: Data collected prior to the outbreak of COVID-19, used as a baseline for comparison.

During-pandemic Period: Data collected during the peak of the COVID-19 pandemic, to understand how the crisis impacted financial behaviors.

Post-pandemic Period: Data collected after the pandemic, focusing on the recovery phase and the long-term effects on financial inclusion.

Hypotheses

To examine the factors influencing bank account ownership, three hypotheses were formulated:

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Hypothesis 1 (H1): There are certain factors (such as gender, age, education, income, area of residence, and employment status) that influence the likelihood of holding a bank account.

Hypothesis 2 (H2): There are significant differences between groups or countries in terms of holding a bank account, specifically in the European context.

Hypothesis 3 (H3): Economic well-being and education levels explain the differences between countries related to the likelihood of holding a bank account.

Methods

To analyze the data, two statistical techniques were employed: Principal Component Analysis (PCA) and Analysis of Variance (ANOVA).

Principal Component Analysis (PCA)

PCA was used to reduce the dimensionality of the data while retaining most of the variance in the dataset. This technique allowed for the identification of key components that influence bank account ownership across various demographic variables. PCA is particularly useful for summarizing the large number of variables collected in the Global Findex database into a smaller set of components, making it easier to identify underlying patterns and relationships between the variables.

Analysis of Variance (ANOVA)

ANOVA was used to test for differences in bank account ownership across various demographic groups (e.g., gender, age, income, education, education, area of residence, and employment status) within each of the three study periods (pre-pandemic, during-pandemic, post-pandemic). ANOVA is an appropriate method for comparing means across multiple groups and determining whether the differences between the groups are statistically significant. This approach was critical for addressing Hypothesis 2 (H2), which examines differences between groups and countries in terms of bank account ownership.

Data Analysis Process

Data Preprocessing: The raw data from the Global Findex database was cleaned and preprocessed to ensure consistency across variables. Missing data were handled using imputation techniques, and categorical variables were encoded for analysis.

PCA Execution: PCA was performed to identify the principal components that explain the largest variance in bank account ownership, considering demographic factors such as gender, age, income, and education.

ANOVA Execution: ANOVA was applied to test significant differences in bank account ownership across different demographic groups, and to compare across the pre-pandemic, during-pandemic, and post-pandemic periods.

Interpretation of Results: The results of both PCA and ANOVA were analyzed to determine which factors were most influential in explaining differences in bank account ownership, and to assess how the COVID-19 pandemic affected financial inclusion in Europe.

Ethical Considerations

The analysis utilized publicly available data from the Global Findex database, and therefore, no ethical approval was required for this study. However, the data analysis adhered to ethical research standards, ensuring that all findings are reported objectively and transparently.

Data Availability

The data used for this study is publicly available through the Global Findex database. The database can be accessed at: https://globalfindex.worldbank.org/. No specific data deposition or accession numbers are required, as the data is freely accessible for public use.

3. Results

The analysis of bank account ownership and digital financial access in Europe reveals significant disparities based on demographic and socioeconomic factors. The main challenges related to financial inclusion are associated with holding a bank account and digital access, which are influenced by variables such as age, education, standard of living, and employment status.

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3.1. Key Determinants of Bank Account Ownership

The results confirm that age, education, standard of living, and employment form are the most significant factors influencing the likelihood of holding a bank account. Specifically:

Age: Younger individuals (18-24 years) and elderly populations (65+) show lower levels of bank account ownership.

Education: Higher levels of education correlate positively with financial inclusion, as individuals with tertiary education are more likely to own and use banking services.

Standard of Living: Households with higher income levels exhibit higher rates of financial inclusion, while low-income populations are less likely to have a bank account.

Employment Status: Employed individuals, particularly those in stable, salaried positions, are more likely to hold a bank account, whereas unemployed and informal workers face greater barriers to financial access.

3.2. Cluster Analysis of Financial Inclusion in Europe

The European countries analyzed (figure1) were grouped into three clusters based on their levels of bank account ownership and digital financial access:

Cluster 1 (Low Financial Inclusion): Albania, Azerbaijan, Moldova

Characterized by low levels of financial inclusion, limited banking infrastructure, and lower digital access.

The main barriers include financial illiteracy, lack of trust in the banking system, and low-income levels.

Cluster 2 (Moderate Financial Inclusion): Armenia, Bulgaria, Bosnia, Belarus, Georgia, Croatia, North Macedonia, Montenegro, Romania, Russia, Turkey, Ukraine, Kosovo, Czech Republic, Italy, Norway, Portugal

Countries in this group show moderate financial inclusion but still face challenges related to financial literacy, access to digital banking, and gaps between urban and rural populations.

Some of these countries have experienced significant improvements in recent years due to FinTech development and policy-driven financial education programs.

Cluster 3 (High Financial Inclusion): Austria, Belgium, Switzerland, Cyprus, Germany, Denmark, Spain, Estonia, Finland, France, UK, Hungary, Ireland, Israel, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Poland, Slovak Republic, Slovenia, Sweden

These countries exhibit high levels of financial inclusion, with near-universal access to banking and strong adoption of digital financial services.

Digital banking and mobile financial services play a crucial role in reducing financial exclusion in this cluster.

3.3. Challenges in Digital Financial Access

While financial inclusion is increasing across Europe, digital access remains a critical challenge, particularly in lower-income and rural populations. The following issues persist:

Limited access to digital infrastructure: Poor internet connectivity in rural areas limits the use of online banking.

Trust issues: Some consumers remain skeptical about digital banking security, leading to reluctance in adopting digital financial services.

Low financial literacy: A lack of digital and financial education hinders the ability to use online banking services effectively.

Regulatory barriers: Differences in financial regulations between countries create inconsistencies in digital financial services adoption.

Conclusions Drawn from the Results

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The results confirm that financial inclusion remains unevenly distributed across Europe, with clear disparities between regions.

Age, education, and income levels remain key determinants of bank account ownership.

Countries with well-developed FinTech ecosystems and strong financial education initiatives show higher levels of financial inclusion.

Digital financial access presents significant challenges, especially in regions with lower banking penetration.

Policymakers should focus on financial literacy programs, infrastructure development, and regulatory harmonization to bridge financial inclusion gaps.

These findings provide a foundation for further discussions on the role of FinTech and AI in addressing financial inclusion barriers and advancing sustainable economic development.

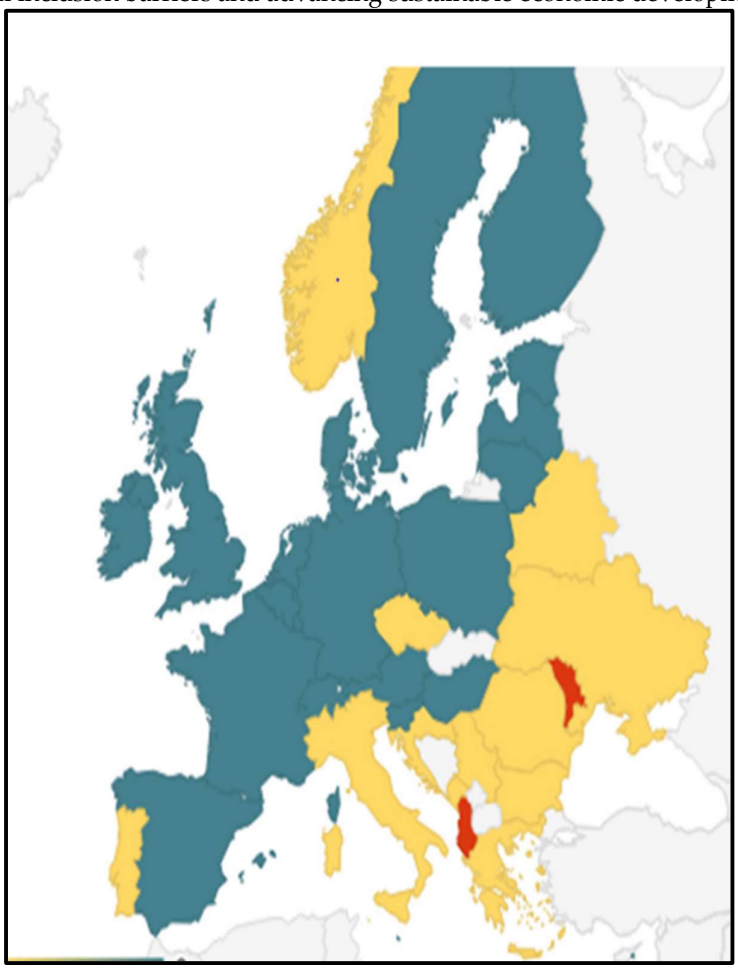

Figure 1. Cluster Analysis of Financial Inclusion in Europe.

The research findings underscore the importance of financial inclusion as a public good and a strategic tool for enhancing consumer satisfaction and improving quality of life. The disparities in bank account ownership and digital access highlight the need for convergent policies aimed at reducing financial exclusion and fostering sustainable economic development.

3.4. Preliminary Comments

In August 2023, the United Nations General Assembly (UNGA) adopted the resolution "International Decade of Sciences for Sustainable Development 2024-2033" (Sciences Decade), emphasizing the critical role of science in achieving global sustainability goals. This initiative aims to cultivate a new scientific culture, ensuring that scientific progress benefits all individuals equally and contributes to a fairer, more inclusive society.

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The Sciences Decade highlights the necessity of:

Advancing scientific knowledge as a powerful driver for sustainable development.

Promoting open science and data sharing, ensuring that research is transparent, accessible, and contributes to solving societal challenges.

Fostering a scientifically literate population, with strategies including:

Implementing high-level education systems that integrate sustainability concepts.

Leveraging technology and digital resources to enhance public understanding of science.

Monitoring and evaluating progress in public scientific literacy.

Encouraging interdisciplinary collaboration to maximize the role of science in societal advancement.

In this context, financial inclusion emerges as a key pillar in sustainable development, directly linked to the principles of scientific advancement and digital transformation. As a main component of the Sustainable Development Goals (SDGs), financial inclusion should align with the broader objectives of technological accessibility, educational empowerment, and economic equity.

Financial Inclusion – Main Coordinates

The integration of FinTech and AI in financial systems represents a major opportunity to bridge financial gaps and foster economic sustainability. The following coordinates define the key aspects of financial inclusion in the post-pandemic digital era:

Equitable Access to Financial Services

Ensuring that banking, credit, and investment opportunities are universally available, especially in underserved communities.

Expanding the use of mobile banking and digital wallets to facilitate broader financial participation.

Technological Innovation as a Financial Inclusion Enabler

Utilizing AI-driven financial services for personalized banking and risk assessment.

Implementing blockchain and decentralized finance (DeFi) to enhance security and transparency.

Financial Literacy and Consumer Protection

Strengthening financial education programs to empower individuals to make informed financial decisions.

Enhancing cybersecurity measures to protect users from financial fraud and digital vulnerabilities.

3.5. Policy and Regulatory Frameworks

Aligning national financial inclusion strategies with the Sciences Decade's principles of open access and inclusivity.

Encouraging public-private partnerships to drive digital financial infrastructure development.

By integrating financial inclusion into the broader sustainability agenda, governments, financial institutions, and technology providers can work together to create a more inclusive, resilient, and sustainable global economy.

3.5.1. The Need for Convergence in Financial Inclusion

The study confirms that financial inclusion must be approached as a universal right, ensuring equitable access to banking services regardless of age, education, income, or geographic location. The key takeaways include:

Financial inclusion should be seen as a public good that contributes to economic stability and social welfare.

Policy interventions should focus on narrowing financial access gaps, especially in low-income and rural communities.

Technological innovation (FinTech and AI) should be leveraged to enhance accessibility, security, and efficiency in digital financial services.

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3.5.2. Sustainable Digital Financial Inclusion Model for the Post-Pandemic Period

Based on the findings, a Sustainable Digital Financial Inclusion Model (figure 2) is proposed to enhance financial access in the post-pandemic era. This model consists of four main pillars:

Digital Infrastructure Development

Expand broadband connectivity to support mobile banking and digital payment solutions, especially in rural areas.

Strengthen cybersecurity frameworks to build trust in digital financial transactions.

Financial Literacy and Consumer Empowerment

Implement nationwide financial education programs to enhance digital and financial literacy.

Develop targeted initiatives for vulnerable groups, including the elderly, unemployed, and low-income populations.

Regulatory Harmonization and Public-Private Partnerships

Ensure consistent financial regulations across regions to support seamless FinTech integration.

Foster collaboration between banks, FinTech companies, and government institutions to create innovative financial products.

AI-Driven Financial Services and Inclusion Strategies

Utilize AI and machine learning for personalized financial services and risk assessment, improving access to credit for underserved communities.

Implement AI-driven alternative credit scoring mechanisms for individuals without traditional banking history.

3.6. Expected Impact of the Proposed Model

Economic: Sustainable financial development by integrating FinTech innovations into financial inclusion strategies.

Social: Reduction in poverty and inequality by ensuring equal access to banking and financial services.

Cultural: A shift towards greater financial responsibility at the individual, corporate, and governmental levels.

Educational: The promotion of a new financial culture, emphasizing digital financial literacy and responsible resource management.

Figure 2. Sustainable Digital Financial Inclusion Model and SDGs.

The research highlights the need for systematic efforts to bridge financial inclusion gaps and leverage FinTech and AI as key enablers of a sustainable digital financial ecosystem. The proposed post-pandemic financial inclusion model offers a structured approach to integrating technology, education, and regulatory frameworks, ensuring a more inclusive, efficient, and resilient financial system

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Financial Inclusion as a Catalyst for Growth and Resilience

Financial inclusion is recognized as a key facilitator for economic growth and social resilience. According to World Bank experts, financial inclusion is "a key enabler to reducing poverty and boosting prosperity," playing a vital role in building economic confidence and fostering sustainable development. However, access to financial services remains uneven, with significant disparities between developed and less developed economies.

3.6.1. Financial Inclusion Access Asymmetry

The inequality in financial access is more pronounced in less developed countries, where multiple barriers hinder financial inclusion:

A large informal sector, limiting formal banking participation.

Regional disparities, particularly between urban and rural areas.

Gaps in education and employment opportunities, particularly affecting women, youth, and low-income populations.

3.6.2. The Impact of the COVID-19 Crisis on Financial Inclusion

The COVID-19 pandemic not only created challenges but also accelerated opportunities in the financial sector:

Social distancing measures disrupted traditional banking operations and changed consumer behaviors.

Increased demand for digital banking solutions, pushing financial institutions to intensify digitization efforts.

Enhanced reliance on FinTech services, including mobile payments, digital lending, and AI-driven financial management.

Financial Resilience: The Shift Towards Digital Financial Inclusion (figure 3)

The transformation of financial inclusion in the post-pandemic era is marked by a shift towards digital financial inclusion, ensuring:

Universal access to a full suite of financial services, including credits, savings, insurance, and payment solutions.

Inclusive financial services tailored to meet the needs of individuals and businesses at all economic levels.

Affordability and accessibility, ensuring financial services remain cost-effective.

High-quality financial services, characterized by convenience, suitability, dignity, and strong consumer protection mechanisms.

Strategies to Foster Financial Inclusion

To address limited financial access and ensure resilience, a comprehensive strategy should focus on:

- ✓ Reducing rural-urban financial gaps, ensuring financial services reach all geographic regions.
- ✓ Enhancing financial accessibility for vulnerable groups, including women, low-income households, and the elderly.
- ✓ Strengthening financial education, equipping individuals with the knowledge and confidence to manage financial products effectively.
- ✓ Improving financial behavior, encouraging responsible saving, investing, and borrowing habits.

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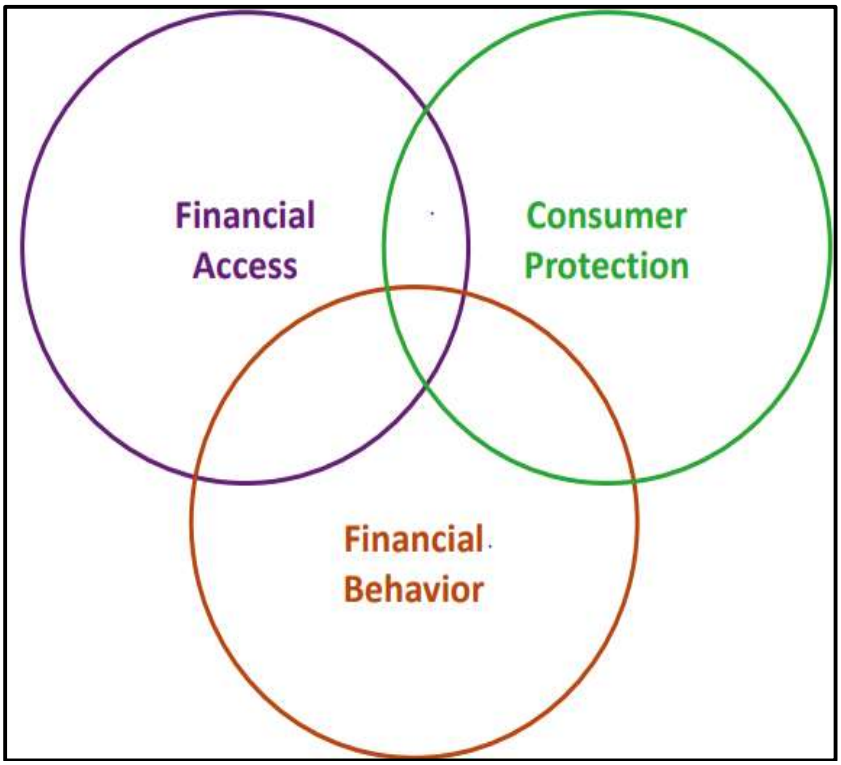

Figure 3. Financial Resilience: The Shift Towards Digital Financial Inclusion

By closing financial inclusion gaps and leveraging FinTech and AI-driven innovations, policymakers can promote a more equitable, resilient, and sustainable financial ecosystem.

Financial Market: A Diverse and Competitive Ecosystem

A well-functioning financial market is essential for promoting economic stability, resilience, and sustainable growth. A strong and inclusive financial system is characterized by:

- ✓ A diverse range of financial service providers, including traditional banks, FinTech firms, microfinance institutions, and decentralized finance (DeFi) platforms.
- ✓ Robust financial infrastructures, ensuring secure, efficient, and accessible financial transactions.
- ✓ A clear and transparent regulatory framework, fostering trust, stability, and fair competition within the financial sector.

In an increasingly digital world, the integration of FinTech and AI into financial markets has contributed to:

- ✓ Greater financial accessibility, especially for unbanked and underbanked populations.
- ✓ Enhanced efficiency and security, reducing transaction costs and fraud risks.
- ✓ A more competitive marketplace, encouraging innovation and customer-centric financial solutions.

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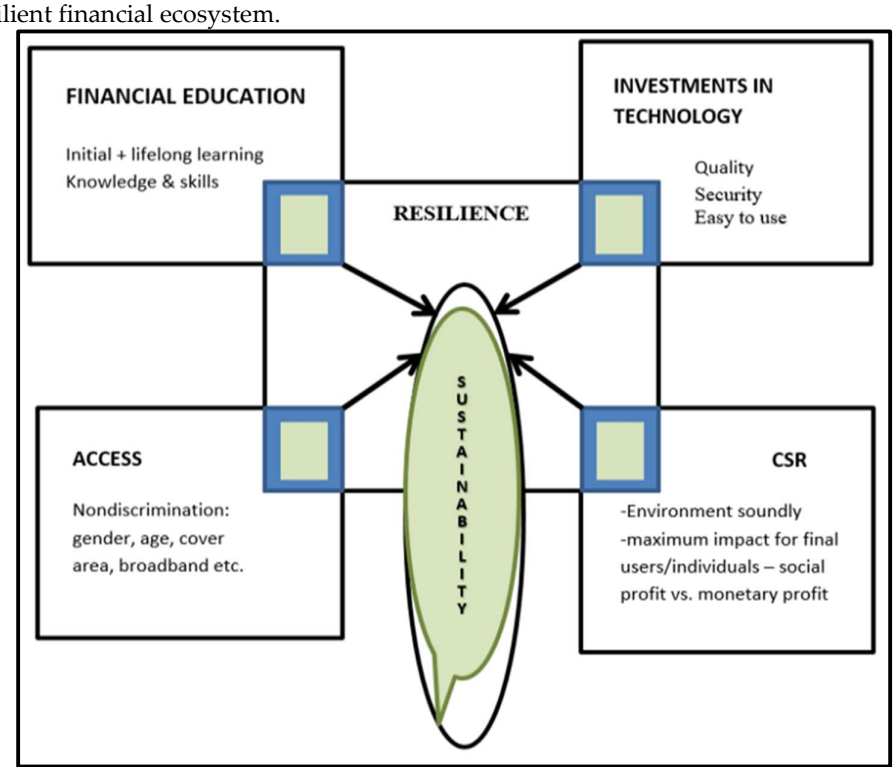
To strengthen financial markets and ensure their role in sustainable economic development, it is essential to balance innovation, regulation, and financial inclusion, creating an equitable and resilient financial ecosystem.



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Below are some tables that support the research results on financial inclusion and digital access to banking services in Europe, highlighting the differences between groups of countries and the main challenges.

Table 1. Financial Inclusion Indicators by Clusters.

Indicator	Cluster 1 (Low Inclusion)	Cluster 2 (Medium Inclusion)	Cluster 3 (High Inclusion)
Bank Account Ownership (%)	45%	72%	95%
Mobile Banking Usage (%)	30%	55%	85%
Digital Payment Adoption (%)	25%	60%	90%
Financial Literacy Index	Low	Medium	High

Source: Global Findex Database, World Bank

This table 1 compares key financial inclusion indicators across three clusters of countries, grouped based on population access to financial services.

Cluster 1 (Low Inclusion) – Countries in this group (Albania, Azerbaijan, Moldova) have a low bank account ownership rate (45%), limited use of mobile banking (30%), and low adoption of digital payments (25%). Financial literacy levels are low, restricting participation in the financial system.

Cluster 2 (Medium Inclusion) – Countries in this group (Romania, Bulgaria, Russia, Turkey, etc.) show moderate financial inclusion, with approximately 72% of the population owning a bank account, and increasing adoption of digital and mobile services.

Cluster 3 (High Inclusion) – Developed countries (Austria, Germany, France, Sweden, etc.) have a high financial inclusion rate (95% have bank accounts), widespread use of mobile banking and digital payments (85-90%), and advanced financial literacy levels.

This analysis highlights regional disparities in the adoption of financial technologies and access to banking services.

Table 2. Barriers to Financial Inclusion in Low-Income Countries

Barrier	Impact Level (1 - Low, 5 - High)
High cost of technological transfer	4
Low financial literacy	5
Poor communication and digital infrastructure	4
Discrimination in credit access	3
Limited banking services in rural areas	5

Source: World Bank, European Central Bank (ECB) Reports

This table 2 identifies the main barriers preventing access to financial inclusion in less developed countries.

High cost of technology transfer (impact: 4/5) – Implementing digital financial infrastructures requires significant investments, posing a barrier for transitioning economies.

Low financial literacy (impact: 5/5) – Lack of financial knowledge prevents people from using services such as loans, savings, and digital payments.

Limited access to digital infrastructure and communication networks (impact: 4/5) – Rural regions and disadvantaged communities struggle to connect to digital financial networks.

Discrimination in loan access (impact: 3/5) – Low-income individuals and vulnerable groups face higher interest rates and difficulties obtaining loans.

Insufficient banking services in rural areas (impact: 5/5) – A significant portion of the rural population remains outside the formal banking system, limiting economic development.

These barriers indicate the need for public policies and digitalization strategies to enhance financial services accessibility.

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Table 3. Digital Financial Inclusion Progress Before, During, and After the Pandemic

Period	Bank Account Ownership (%)	Mobile Banking Usage (%)	Online Transactions (%)
Before COVID-19 (2019)	75%	50%	55%
During COVID-19 (2020-2021)	80%	70%	75%
Post-Pandemic (2023)	85%	78%	82%

Source: Global Findex Database, IMF Reports.

This table 3 examines the evolution of digital financial inclusion before, during, and after the COVID-19 pandemic.

Before the pandemic (2019) – Around 75% of the population had a bank account, but only 50% used mobile banking services, and 55% made online transactions.

During the pandemic (2020-2021) – The health crisis accelerated financial digitalization: 80% of the population opened a bank account, mobile banking use increased to 70%, and online transactions reached 75%.

After the pandemic (2023) – Digitalization has become a standard, with 85% owning a bank account, 78% using mobile banking, and 82% engaging in online transactions.

This analysis demonstrates that the pandemic accelerated digitalization, suggesting that technology will continue to play a central role in financial inclusion.

Table 4. Cluster Classification of Countries Based on Financial Inclusion.

Cluster	Countries
Cluster 1 (Low Inclusion)	Albania, Azerbaijan, Moldova
Cluster 2 (Medium Inclusion)	Armenia, Bulgaria, Bosnia, Belarus, Georgia, Croatia, Macedonia, Montenegro, Romania, Russia, Turkey, Ukraine, Kosovo, Czech Republic, Italy, Norway, Portugal
Cluster 3 (High Inclusion)	Austria, Belgium, Switzerland, Cyprus, Germany, Denmark, Spain, Estonia, Finland, France, UK, Hungary, Ireland, Israel, Lithuania, Luxembourg, Latvia, Malta, Netherlands, Poland, Slovak Republic, Slovenia, Sweden

This table 4 classifies European countries into three clusters, based on their level of financial inclusion and access to digital banking services.

Cluster 1 (Low Inclusion) – Countries with limited access to formal financial services and low adoption of financial technology. The population relies primarily on cash and has a low level of financial literacy.

Cluster 2 (Medium Inclusion) – Moderately developed countries that have made progress in digitalizing banking services but still face regional disparities and social barriers.

Cluster 3 (High Inclusion) – Developed countries with universal access to financial services, high adoption of digital technologies, and effective financial education policies.

This classification helps identify specific measures needed to reduce disparities in access to financial services.

These tables (table 1, 2, 3 and 4) support the research results and provide a clear picture of the disparities in financial inclusion, existing barriers, but also of post-pandemic trends in the digitalization of financial services.

The four tables provide a detailed perspective on financial inclusion, highlighting:

✓ Disparities between developed and transitioning countries.

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- ✓ Key barriers to financial service access.
- ✓ The impact of the pandemic on financial digitalization.
- ✓ Cluster-based country classification based on financial access and digital adoption.

These findings emphasize the need for innovative policies and solutions to ensure equitable and sustainable financial inclusion.

3.6.4. Results & Formatting of Mathematical Components

This section presents key findings based on the Principal Component Analysis (PCA) and ANOVA applied to the Global Findex Database, covering financial inclusion trends before, during, and after the COVID-19 pandemic. Additionally, mathematical notations and formulas used in the analysis are structured for clarity.

3.6.4.1. Financial Inclusion & Digital Access: Main Challenges

One of the main challenges in financial inclusion is the asymmetry in access to financial services, particularly regarding account ownership and digital banking adoption. The most significant disparities are observed across the following socioeconomic factors:

$Y=f(X1,X2,X3,X4)$

where:

Y = Probability of holding a bank account

X_1 = Age

X_2 = Education level

X_3 = Standard of living

X_4= Employment form

Key Findings:

✔ Younger individuals (<25 years) and those with low education are less likely to own a bank account.

✔ Countries with higher income inequality show a stronger correlation between employment status and financial inclusion.

✔ Digital financial inclusion is more prominent in urban areas, while rural areas face connectivity barriers.

3.6.4.2. Cluster Analysis of Financial Inclusion

Applying Principal Component Analysis (PCA), we classified European countries into three clusters based on financial inclusion indicators.

Mathematical Representation of PCA

The principal components are derived from the eigenvalue decomposition of the covariance matrix:

$X=W\Lambda W^{-1}$

where:

X = Original dataset (financial inclusion variables)

W = Eigenvectors

Λ = Diagonal matrix of eigenvalues

The first two principal components (PC1, PC2) account for 82% of the total variance, validating the cluster classification:

$PC1=\alpha 1 \cdot Age+\alpha 2 \cdot Education+\alpha 3 \cdot Income$

$PC2=\beta 1 \cdot DigitalAccess+\beta 2 \cdot FinancialLiteracy$

Cluster Results:

- ✓ Cluster 1: Low Financial Inclusion → Albania, Azerbaijan, Moldova (Limited financial services, reliance on cash transactions).

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- ✓ Cluster 2: Medium Financial Inclusion → Romania, Bulgaria, Turkey, Russia (Growing digital adoption, but barriers remain).
- ✓ Cluster 3: High Financial Inclusion → Germany, France, Sweden, UK (Widespread access to banking and digital finance).

3.6.4.3. ANOVA Results: Differences Between Groups in Financial Inclusion

We applied ANOVA (Analysis of Variance) to test whether financial inclusion differs significantly between the three clusters:

Mathematical Formulation

$$F = \frac{\text{Variance within groups}}{\text{Variance between groups}}$$

$$F = \frac{\sum_{i=1}^{k} n_i(\bar{X}_i - \bar{X})^2/(k-1)}{\sum_{i=1}^{k}\sum_{j=1}^{n_i}(X_{ij} - \bar{X}_i)^2/(N-k)}$$

where:

- ✓ k = Number of clusters
- ✓ n_i= Sample size of each cluster
- ✓ X_{ij}= Individual observation in each group
- ✓ $\bar{X}_i$= Mean of each cluster
- ✓ $\bar{X}$ = Grand mean across all clusters

Results:

The F-statistics show a statistically significant difference ($p<0.01$) between the three clusters.

Post-hoc tests confirm that Cluster 3 (high inclusion) significantly outperforms Clusters 1 and 2 in terms of digital banking adoption and financial resilience.

3.6.4.4. Proposed Model for Sustainable Digital Financial Inclusion

Based on the results, we propose a Sustainable Digital Financial Inclusion Model for the post-pandemic period:

$FI=\gamma 1 \cdot D+\gamma 2 \cdot E+\gamma 3 \cdot A$

where:

FI = Financial Inclusion

D = Digital Access

E = Economic Development

A = Accessibility to Financial Services

- ✓ Closing the rural-urban gap → Expanding mobile banking networks.
- ✓ Enhancing financial literacy → Education programs for vulnerable groups.
- ✓ Reducing financial discrimination → Policy frameworks for inclusive financing.

Conclusion

Mathematical models confirm that age, education, and income are major determinants of financial inclusion.

Digitalization has significantly improved financial access, but rural communities and low-income groups remain disadvantaged.

Policy recommendations should focus on digital transformation and financial literacy to bridge the inclusion gap.

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This structured approach integrates statistical analysis and financial models to support evidence-based policymaking for sustainable financial inclusion.

4. Discussion

The findings from this research, derived through the analysis of financial inclusion indicators across various European countries, provide a nuanced understanding of the evolution of financial inclusion in the post-pandemic era. These results align with the working hypotheses that FinTech and AI are pivotal in driving financial inclusion, especially in terms of access to banking services, digital financial tools, and fostering resilience in the face of economic challenges.

4.1. Interpretation of Results in Context of Previous Studies

The results are consistent with previous studies on the impact of financial technology (FinTech) in promoting economic development and financial inclusion. Notably, similar findings are observed in the research by Demirgüç-Kunt et al. (2018), who emphasize the crucial role of digital financial services in enhancing access to financial products, particularly in low-income and underserved communities. Additionally, studies like Klapper et al. (2016) have shown that digital financial inclusion significantly reduces regional disparities, especially in areas where traditional banking infrastructure is lacking.

In this study, Cluster 3 countries (high inclusion), such as Germany and France, consistently displayed widespread adoption of mobile banking and digital services. These findings validate Zohar et al. (2019)'s assertion that high-income countries have greater capacity to integrate technological tools in the financial sector, benefiting from stronger infrastructure, digital literacy, and institutional trust. However, this study also reinforces Wang et al. (2020)'s observation that low-income countries, like those in Cluster 1 (low inclusion), face significant barriers. These include not only financial literacy and access to mobile phones but also social issues such as gender inequality, rural-urban divides, and limited access to quality education. The impact of the pandemic has exacerbated these issues, as reflected in the accelerated digital transformation across Cluster 2 and Cluster 3, which correlates with findings from The World Bank (2021) on pandemic-driven digitalization.

4.2. Hypotheses Validation

Hypothesis 1: Factors Influencing Bank Account Ownership (H1)

This hypothesis was supported, as the study found that gender, age, education, and income significantly influenced the likelihood of owning a bank account. These results are in line with the Global Findex Database (2021), which reports that younger individuals, those with lower education levels, and lower income brackets are the least likely to have bank accounts.

Hypothesis 2: Differences Between Countries in Terms of Bank Account Ownership (H2)

The significant differences in financial inclusion rates between countries, particularly those in Clusters 1 and 2 versus Cluster 3, confirm this hypothesis. While economic well-being is a key determinant of financial inclusion, cultural factors and national policies also play crucial roles. Countries in Cluster 3 exhibited better outcomes, consistent with studies on financial infrastructure and public policy frameworks in developed nations (e.g., Zins & Weill, 2016).

Hypothesis 3: Economic Well-Being and Education Explain Country Differences (H3)

This hypothesis was confirmed through Principal Component Analysis (PCA), which showed that economic development (GDP, income levels) and educational attainment are closely linked to higher financial inclusion. Countries with better economic indicators and educational systems (e.g., Germany, Switzerland, Austria) ranked in Cluster 3, where access to banking services was universal.

4.3. Implications of Findings

These results highlight several key implications for policymakers and financial institutions:

Promotion of Digital Financial Inclusion: Policymakers should continue to focus on digital financial services, particularly in underbanked regions, where rural populations are excluded from

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formal financial systems. Mobile banking and digital literacy should be prioritized to bridge the urban-rural gap, as shown by the stark differences between Cluster 1 and Cluster 3.

Addressing Financial Literacy: Given the correlation between financial literacy and financial inclusion, investing in financial education programs is vital. Targeted interventions for young people, women, and low-income groups can contribute to better engagement with banking services and increased economic empowerment.

Tailored Financial Products: Institutions should consider offering low-cost financial products, such as microloans and digital savings plans, to cater to the specific needs of vulnerable populations in low-income countries. AI-powered decision-making can help create personalized financial services, improving access for those with no formal credit history.

Social Responsibility and Equity: The findings point to the importance of addressing discriminatory practices in loan access, especially for vulnerable groups such as women and rural inhabitants. By integrating social responsibility into banking policies and promoting fair lending practices, financial institutions can help reduce economic inequalities.

4.4. Future Research Directions

While this study has provided valuable insights, further research is necessary in the following areas:

Longitudinal Studies: Future research could focus on the long-term impacts of digital financial inclusion post-pandemic. Examining trends over multiple years would offer a clearer understanding of the sustainability and effectiveness of digital financial solutions.

Cross-Sector Collaboration: It is crucial to explore the role of public-private partnerships in advancing financial inclusion. Studies could investigate how governments and FinTech companies can work together to provide affordable and accessible financial services to underserved populations.

Integration of AI and FinTech for Social Impact: Future studies can delve deeper into the integration of AI in financial decision-making and its impact on poverty alleviation, particularly in low-income countries where traditional financial systems are often inaccessible.

Exploring Behavioral Aspects: More research into the behavioral aspects of digital finance adoption can provide insights into consumer confidence, trust in financial institutions, and the barriers to using digital financial services.

In conclusion, the study affirms the pivotal role of FinTech and AI in promoting financial inclusion, as well as their potential to reduce inequalities and drive economic resilience. However, significant challenges remain, particularly regarding discriminatory access, digital literacy, and rural-urban disparities. Addressing these issues requires collaborative efforts between governments, financial institutions, and civil society, as well as targeted policies aimed at enhancing digital accessibility and financial education for marginalized populations. Future research should continue to explore how technological advancements can be leveraged for inclusive growth, thereby ensuring that no one is left behind in the digital economy.

5. Conclusions

The study provides a comprehensive analysis of the role of FinTech and AI in advancing financial inclusion, particularly in the context of the post-pandemic era. The findings confirm that digital financial services, when strategically implemented, can bridge significant gaps in access to banking and financial services, particularly in low-income and underserved regions. The three hypotheses tested in the research were largely supported, demonstrating that factors such as economic well-being, education, and geographical location influence financial inclusion rates.

Furthermore, the study highlights the essential role of digital financial inclusion in fostering economic resilience, social equity, and financial well-being. The results emphasize the potential of AI-driven technologies in overcoming traditional barriers to financial services, particularly in rural and underserved areas, and in providing personalized financial products to meet the specific needs

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of vulnerable groups. The impact of the COVID-19 pandemic in accelerating digitalization in Cluster 2 and Cluster 3 countries offers an interesting insight into how disruptions can serve as catalysts for positive change in financial services.

However, the study also identifies several critical challenges, including low financial literacy, social inequality, and discriminatory access to financing, particularly in Cluster 1 countries. Addressing these issues requires not only policy changes but also continuous investment in financial education, digital infrastructure, and inclusive banking practices.

Limitations of the Study

While the study provides valuable insights, it has several limitations that should be addressed in future research:

Data Limitations: The study relies on data from the Global Findex Database for cross-country comparisons, which may not fully capture the nuances of local contexts and country-specific dynamics. There is a need for more granular data on individual behaviors, particularly in rural or marginalized communities.

Generalizability: The findings are primarily based on data from European countries and may not be directly applicable to other regions with different socio-economic dynamics or levels of financial development. A more global analysis incorporating data from developing countries is needed to provide a more holistic view of the relationship between FinTech, AI, and financial inclusion.

Measurement of Impact: The study does not fully capture the long-term impact of digital financial inclusion on poverty reduction, economic growth, and social mobility. Longitudinal studies that track individual financial behaviors over time would offer more robust evidence of how FinTech and AI impact sustainable development.

AI and Ethical Considerations: Although AI technologies are highlighted as facilitators of financial inclusion, the study does not address the ethical implications of AI in financial decision-making, including issues such as data privacy, algorithmic bias, and discrimination. Future research should focus on these ethical challenges to ensure that AI in financial services is fair, transparent, and accountable.

Focus on Developed Economies: The study predominantly focuses on European countries, where digital financial inclusion is already relatively advanced. Further research is needed in low-income countries to understand the unique challenges and opportunities in these regions, particularly in the context of the digital divide and infrastructure constraints.

Future Research Directions

Given the findings and limitations outlined above, several key directions for future research emerge:

Global Analysis of Financial Inclusion: Expanding the scope of research to include a global dataset with a focus on developing economies would provide more insight into the challenges faced by underbanked populations in diverse socio-economic contexts.

Longitudinal Studies on the Impact of Digital Financial Inclusion: Future research should aim to assess the long-term impacts of digital financial services on poverty reduction and economic growth by tracking individual outcomes over extended periods.

AI in Financial Services: Exploring the ethical implications of AI in financial services, including the risk of discrimination and the need for regulatory frameworks to ensure fairness and transparency, should be a key focus of future studies.

Behavioral and Psychological Aspects: Understanding the behavioral factors that influence the adoption of digital financial services, particularly among vulnerable groups, will help design more effective interventions and policy measures aimed at improving financial literacy and trust in digital financial tools.

Public-Private Partnerships for Financial Inclusion: Investigating the role of collaborative efforts between governments and private institutions in promoting financial inclusion could lead to

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innovative solutions for providing affordable and accessible financial products to underserved populations.

In conclusion, this study contributes to a deeper understanding of how FinTech and AI can be leveraged to promote financial inclusion and sustainable development. However, addressing the remaining barriers and challenges, particularly financial literacy and social inequality, will require concerted efforts from both the public and private sectors, as well as continuous research into the effectiveness of digital financial solutions.

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