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Digital finance research and developments around the World: a literature review

Peterson K. Ozili

Abstract

This paper presents a concise review of the existing digital finance research in the literature, and highlight some of the developments in digital finance around the world. The paper reached several conclusions. Firstly, it showed that digital finance has become an important part of modern finance and the major application of digital finance can be found in Fintech, embedded finance, open banking and decentralized finance, central bank digital currencies, among others. Secondly, it identified some international determinants of digital finance which includes the need for efficiency in financial services delivery, the need to achieve the United Nations sustainable development goals using existing digital technologies, the need to increase financial inclusion through digital financial inclusion and the need for efficient payments and payment settlement finality. The paper also finds that digital finance research is growing fast, and recent studies have investigated contemporary issues in digital finance that are relevant for policy and practice. Regarding the digital finance developments around the world, the paper shows that the Fintech and mobile money industries are the largest beneficiary of investments in digital finance with the total number of users of mobile money services surpassing 1 billion globally. Also, the paper predicts that the future of digital finance is to create a digital environment that permits the offering of all kinds of financial product and services that can be customized and personalized to meet the unique needs of all users on a single digital platform and without requiring any form of human assistance or intermediary. The paper then suggest some areas for future research which include the need for more research on how regulators can keep pace with emerging digital finance transformation, the need for more research on user information security and compliance, the need for more research on how to deal with bias caused by bad data, the need for more research on how to deal with algorithmic bias, and the need for more research on how to combine a risk-conscious culture with a higher risk appetite for digital finance transformation.

Keywords: digital finance, artificial intelligence, machine learning, financial inclusion, fintech, access to finance, financial stability, economic growth, blockchain, central bank digital currency, robotics, cryptocurrency.

JEL code: E44, F65, G18, G21, G28.

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1. Introduction

Digital finance deals with using digital devices and digital technology to acquire, use and distribute financial resources to economic agents such as individuals, households, firms and government (Siddik and Kabiraj, 2020; Ozili, 2018). The use of digital technology in finance began in the early 2000s during the dot.com bubble. Digital finance innovations became prominent after the 2007 to 2009 global financial crisis as financial began to use digital technology to process cross border payments, to manage customers' account, to save cost and to maximize profits.

Generally, digital technology in finance has aided the rapid development of the financial sector of many developed countries by increasing the speed of the transmission of financial market information to investors, shareholders and other market participants, and by increasing the speed of financial transactions, payments, and payment settlement finality (Bech et al, 2017; Shabsigh et al, 2020). In developing countries, the use of digital technology in finance has helped to increase the size of remittance inflows and has contributed to high levels of financial inclusion (Podolski, 2020; Emara and Zhang, 2021).

Digital finance, while being important, has also become the subject of enormous debate. The debate is centered on five main themes: debates about the net welfare benefits of digital finance (Ozili, 2018), debates about the structure and size of transaction cost associated with using digital finance applications (Nagle et al, 2020; Gille, 2005), debates about which aspects of finance should be digitized and which should not be digitized (Ozili, 2021a), debates about the voluntary or involuntary use of digital financial services (Ozili, 2021a), and debates about how to handle and secure the large data or 'big data' that arises from digital financial transactions (Beaumont, 2019; Schiff and McCaffrey, 2017). These debates have led to calls to more regulation, that is, to regulate the digital finance ecosystem and enact legislation to protect users' digital data. While these developments are important from a safety point of view, they show that digital finance comes with some issues. Consequently, providers and users of digital financial products and services need to understand these issues, so that providers of digital financial products and services can conveniently provide access to finance to users, and users can use digital financial services safely and in an environment of trust.

Another important area, which is central to this paper, is the global developments in digital finance in several parts of the world. Understanding these developments can help us understand the determinants of digital finance and whether digital finance enhances globalization. Such knowledge can also help us gain some insight into whether digital finance is evolving too fast and can help us make predictions about the future of digital finance. Such knowledge can also provide insights about the risks of international digital finance. To explore this important area of digital finance, this paper survey the existing research on digital finance and uses real-world experiences in digital finance developments. Accordingly, this paper reviews the existing research on digital finance and uses relevant real world experiences from several regions to gain insight into the state of digital finance research and development. This paper is one of the first papers to review the global developments in digital finance.

This paper contributes to the literature in the following ways. Firstly, the paper contributes to the literature that examine the role of the internet and digital technology in finance. It contributes to this literature by exploring the potential to increase access to finance for all economic agents by using digital technology enabled by the internet. Secondly, this paper contributes to the financial innovation literature. Studies in this literature include Tufano (2003), Laeven et al (2015), Bernier and Plouffe (2019), etc. This paper contributes to this literature by showing that many financial innovations are built using digital technology and rely on digital technology to function. Thirdly, this paper contributes to the digital finance literature. Studies in this literature include Gomber et al (2017), Ozili (2018), etc. This paper contributes to the digital finance literature by providing a much needed futurist review of the state of digital finance research and development, and it makes predictions about the future of digital finance in 10 to 20 years' time from now.

To begin, section 2 shows the importance of digital finance. Section 3 highlights the modern application of digital finance. Section 4 presents the international determinant of digital finance. Section 5 presents a concise review, or a summary, of post-2010 digital finance research in the literature. Section 6 identifies some of the developments in digital finance around the world. Section 7 offers a prediction about the future of digital finance. Section 8 suggest some directions for future research. Section 9 concludes.

2. Importance of digital finance

Why is digital finance important? Digital finance is very important to modern finance for many reasons. One, digital finance is important because almost all forms of financial instruments in global financial markets are traded using digital financial platforms, technologies or infrastructure (Moşteanu, 2019; Feyen et al, 2021). Two, digital finance is important is because most of the disruptive innovations in finance today such as private digital currency, cryptocurrency, embedded finance, internet finance, blockchain finance, decentralized finance, artificial intelligence (AI) finance and central bank digital currency are all the outcome of varying degree of advancement in digital finance (An et al, 2021; Wullweber, 2020; Zetzsche et al, 2020a; Ozili, 2019). Three, digital finance is important because digital finance offers convenience to users by saving the time and transportation costs that users would incur to visit a financial institution to perform basic financial transactions (Nagle et al, 2020; Ozili, 2018). Four, digital finance is important because it allow providers of finance to focus on improving the efficiency of their financial product and service offering rather than spending too much time in resolving soft issues e.g. human-side issues (Wang et al, 2020). Five, digital finance is important because it can increase financial inclusion by bringing unbanked adults into the formal financial sector so that they can have access to finance (Ozili, 2018; Durai and Stella, 2019; Ozili, 2021c). Finally, digital finance is important because it increases consumption spending and investment thereby contributing to economic growth (Li et al, 2020; Guo et al, 2021; Sadigov et al, 2020).

3. Modern developments in digital finance

Over the years, digital finance has evolved in remarkable ways. Today, digital finance manifests through internet finance, fintech finance, embedded finance, artificial intelligence finance, blockchain finance, decentralized finance, etc. We then proceed to define these concepts.

Internet finance is financial services that is offered over the internet using a network which may be an analog network or a digital network. Internet finance facilitates financing, payment, investment, and information intermediary services by the internet (Hou et al, 2016). **Fintech finance** is financial services that is offered by financial technology companies. Fintech companies

use technology to enhance or automate financial services and processes which are then delivered to customers in a frontend user interface commonly referred to as user applications (Lai et al, 2017; Guild, 2017). **Open banking** is a type of digital technology application in banking and finance. Open banking is the use of open APIs that enable third-party developers to build applications and services around a bank or financial institution (Mansfield-Devine, 2016). **Embedded finance** is simply the integration of financial services into the service or product of a non-financial institution. Embedded finance is about enabling non-financial services companies to provide financial services to customers. Embedded finance involves embedding financial services as an add-on service into the business processes of non-financial institutions. It allows customers to access financial services in a non-financial service shop such as in a grocery store, a car dealership, a hospital or within a non-financial app. In banking, embedded finance enables non-financial services companies to provide banking services. This is possible by using Banking-as-a-Service (BaaS) and API-driven banking and payments services to integrate banking services within a non-financial environment and ecosystem. **Decentralized finance** is a type of blockchain-based digital finance. Decentralized finance transforms traditional financial products into products that operate without an intermediary through smart contracts on a blockchain (Avgouleas and Kiayias, 2020). Decentralized finance is financial services offered on a public blockchain over the internet. It does not rely on centralized financial intermediaries such as brokerages, exchanges, or banks. It uses smart contracts on blockchains, mostly Ethereum. It is mostly built on top of peer-to-peer and trustless networks. Decentralized finance is also viewed as the democratization of finance. **Blockchain finance** is financial services that is delivered over the blockchain. It involves delivering financial services on a digitally distributed, decentralized, public ledger that exists across a network (Ozili, 2019). **Artificial intelligence finance** is the use of advanced robotic systems to enhance financial decision making and to streamline and optimize specific financial activities (Veloso et al, 2021; Mancher et al, 2018). Artificial intelligence finance improves the predictive power of financial models and leads to better management of risk and better decision making (Hilpisch, 2020). **Electronic money**, or eMoney, is an area of digital finance that focuses on the conversion of traditional paper money into a digital medium of exchange to improve the efficiency of payments. Electronic money is best defined as money in digital form or

the virtual equivalent of paper money (Wulandari et al, 2016). Electronic money that is issued by private or non-state actors are referred to as private digital currencies or cryptocurrencies such as bitcoin, ethereum, litecoin, dogecoin, etc, while electronic money that is issued by state actors or a central bank is known as fiat digital currency or central bank digital currency (CBDC).

4. International determinants of digital finance

The section explores the major factors that explain the increasing demand for digital technology in financial services. The first determinant is the need to increase efficiency in financial services delivery. Efficiency in financial services delivery is achieved by reducing the cost of financial services. Financial institutions use digital technology to automate repetitive human tasks in the financial sector in order to reduce in labour costs. The resulting cost savings from automating repetitive human tasks leads to a reduction in the cost-to-income ratio of financial institutions and increase their profit margins in the long run.

The second determinant is the need to achieve the United Nations sustainable development goals (SDGs) using existing digital technologies. The expectation is that adopting digital technology in finance can help to achieve some, if not all, of the 17 United Nations SDGs. Digital finance offers greater access to finance for poor people, small businesses and large firms. For instance, digital financial services such as online quick loan and instant stock purchase allows poor people and small businesses to use available loan and investment products to increase consumption and investment expenditures, thereby reducing extreme poverty, extreme hunger and income inequality. It also provides an opportunity to use credit to fund and acquire quality education and to support productive economic activities that lead to economic growth.

The third determinant is the need to increase financial inclusion through digital financial inclusion. Financial inclusion is aimed at increasing the number of banked adults in society. Governments around the world want higher levels of financial inclusion because greater financial inclusion increases the tax revenue of governments and reduces the size of the informal economy. Digital financial inclusion ensures that individuals have a formal digital identification credential that enables them to remotely access a wide range of digital financial services in the

formal financial sector. The digital credential offers convenience to users as it allows users to access formal financial services without needing to visit the physical location of a financial institution. The benefit to users is the convenience and cost savings it offers while the benefit to governments is the increase in digital financial transactions which can be easily taxed to generate substantial revenue for the government.

The fourth determinant is the need for efficient payments and payment settlement finality. Provided that there is a reliable payments system, using digital technology to facilitate payment can improve the efficiency of payments by facilitating the transfer of value from a sender to the receiver, providing real-time confirmation of the value transferred on the receiver's digital device, and notifying the sender of any failure in transferring value from the sender to the receiver so that the sender can either re-initiate the value transfer or take some other action. Digital technology in the payments system can also improve payment settlement finality especially for within border and cross border transactions. Settlement finality, also known as final settlement, is the irrevocable and unconditional transfer of an asset or financial instrument, or the discharge of an obligation by the securities settlement facility or its participants in accordance with the terms of the underlying contract (RBA, 2012). Digital technology in the payments system can assist parties in the discharge of contractual settlement obligations after they have received an irrevocable and unconditional request to transfer an asset or financial instrument from one party to another. Digital technology in the payments system can be used to remind parties of the need to fulfil their contractual settlement obligations and can also be used to notify parties of the consequences of a breach in fulfilling their contractual settlement obligations.

5. Review of post-2010 digital finance research – a concise summary

This section presents a summarized report of the findings of post-2010 digital finance research. The studies reviewed in this section were obtained after conducting a search on google scholar search engine. There are **six** broad research themes in the post-2010 digital finance literature.

The first theme relates to studies that highlight the benefits of digital financial services or the benefits of digital finance. The literature show that digital finance can increase financial inclusion

and expand financial services to nonfinancial sectors (see Ozili, 2018; Siddik and Kabiraj, 2020). Digital finance can increase the gross domestic product of several economies (see Zhang and Chen, 2019; Ozili, 2018). Digital finance can improve bank performance in the long run (see Phan et al, 2020; Ozili, 2021b). Digital finance can increase aggregate expenditure and generate higher tax revenue (see Ozili, 2018). Digital finance via digital payments can reduce the circulation of counterfeit paper money and can reduce the use of counterfeit money to make payments (see Ozili, 2018). Digital finance gives users greater control of their personal finance (see French et al, 2021; Ozili, 2018). Digital finance applications have tools that aid quick financial decision making (see Guo et al, 2021; Ozili, 2018). Digital finance helps to reduce money laundering which is commonly associated with cash transactions (see Oxford Analytica, 2021)

The second theme relates to studies that examine the impact of digital finance on specific areas of the economy or the wider economy. These studies show that digital finance has a positive effect on financial stability through greater financial inclusion (see Ozili, 2018; Siddik and Kabiraj, 2020). Other studies show that digital finance improves access to finance (see Bollaert et al, 2021; Creehan, 2019), enhances the efficiency of the financial sector (see Wang et al, 2020), and enhances the functioning of capital markets (see Wales, 2015). There is evidence that digital finance can help the economy recover quickly from a recession caused by a financial crisis or a health pandemic (see Arner et al, 2020; Curran, 2020), and it can support climate change mitigation efforts (see Puschmann et al, 2020; Tao et al, 2022). There is also evidence that digital finance has helped to grow several sectors of the economy such as the equity crowdfunding industry (see Butticè and Vismara, 2021), the energy sector (see Winiacki and Kumar, 2014), the agricultural sector (see Babcock, 2015), the manufacturing sector (see Chen and Zhang, 2021), the banking sector (see Jünger and Mietzner, 2020), the circular economy (see Bressanelli et al, 2018), the tourism sector (see Adeola and Evans, 2019), the external trade sector (see Abendin and Duan, 2021), amongst others.

The third theme relates to studies that examine the impact of digital finance on one or more aspects of human development and welfare. Existing studies show that digital finance enhances human development and improves welfare by improving household consumption (Li et al, 2020), gender equality (Kusimba, 2018), women participation in the economy (Kofman and Payne,

2021), reducing transaction cost for households (Ozili, 2018), reducing gender inequality (Sorgner et al, 2017), reducing extreme poverty (Chen and Zhao, 2021) and reducing income inequality (Das and Chatterjee, 2021).

The fourth theme relates to studies that examine country-specific use case of digital finance innovations such as the M-Pesa in Kenya (see Kingiri and Fu, 2019; Ndung'u, 2018), the Pradhan Mantri Jan-Dhan Yojana (PMJDY) scheme in India (see Markose et al, 2020; Tiwari et al, 2019), the large scale use of point-of-sale (POS) devices and unstructured supplementary service data (USSD) technology to facilitate digital financial transactions in countries like Bangladesh, Nigeria and South Africa (see David-West, 2016; Peter et al, 2018), among others.

The fifth theme relates to studies that identify the challenges of digital finance. Some of the challenges identified in the literature include: the potential risks to national security (Reshetnikova et al, 2021), lack of appropriate and timely regulation as well as poor quality and unaffordable digital connectivity (Ketterer, 2017), the difficulty in getting merchants to accept digital payments for small purchases (Ozili, 2018), high transactions cost that could erode the small income of poor and low-income households coupled the low level of financial literacy among the poor and rural population (Ozili, 2020), etc.

The sixth theme relates to studies that examine the regulation of the digital finance ecosystem. There is the argument that the emerging risks of digital finance is a justification to regulate it (Michaels and Homer, 2018). There is also the argument that digital finance regulation should create an enabling environment to nurture innovation and create a level playing ground for incumbent players in the digital finance ecosystem while at the same time providing regulatory sandboxes to protect new digital finance players that are in their early stages of development (see Shulist, 2018; Alam et al, 2019). The aim of digital finance regulation is to meaningfully regulate digital finance without stifling innovation (Pavlidis, 2021). And when a digital finance regulatory has been developed, there should be continuous improvements to the regulatory framework from time to time (Zetzsche et al, 2020b).

Overall, the review shows that digital finance research is growing fast, and many studies have investigated contemporary issues in digital finance which are relevant for policy and practice.

6. Regional developments in digital finance: real world experiences

6.1. Global development

There are over 2 billion unbanked adults in the world. Digital financial services have the potential to increase the GDP of developing and emerging countries by US\$3.7 trillion and has the potential to create 95 million jobs across all sectors (Manyika et al, 2016). Fintech have dominated much of the global digital finance space with global Fintech revenues rising from €92 billion in 2018 to over €188 billion in 2024.¹ Also, global mobile money services increased by 20% in transaction value in 2020 as shown in table 1. The largest increase was recorded in the East Asia and Pacific region, the Latin America and the Caribbean region and the Europe and Central Asia region respectively. The sub-Saharan African region and the Middle East and North Africa region recorded a relatively slow growth in global mobile money services.

Table 1. 2020 Global Mobile Money Statistics

	Mobile money deployment live services	Number of registered accounts	Number of active accounts	Transaction volume	Transaction value (US\$)
Global	310	1.2 billion (+13% from 2019)	300 million (+17% from 2019)	41.4 billion (+15% from 2019)	767 billion (+22% from 2019)
East Asia and Pacific	49	243 million (+24% from 2019)	52 million (+20% from 2019)	5.4 billion (+26% from 2019)	111 billion (+34% from 2019)
Europe and Central Asia	9	21 million (+6% from 2019)	4 million (+11% from 2019)	234 million (+15% from 2019)	4.0 billion (+13% from 2019)
Latin America and the Caribbean	30	39 million (+38% from 2019)	16 million (+67% from 2019)	701 million (+35% from 2019)	19.8 billion (+30% from 2019)
Middle East and North Africa	29	56 million (+9% from 2019)	3 million (+35% from 2019)	146 million (-63% from 2019)	10.5 billion (+26% from 2019)
South Asia	36	305 million (+5% from 2019)	66 million (+5% from 2019)	7.5 billion (+8% from 2019)	131 billion (+10% from 2019)
Sub-Saharan Africa	157	548 million (+12% from 2019)	159 million (+18% from 2019)	27.4 billion (+15% from 2019)	490 billion (+23% from 2019)
(source: GSMA 2021 report)					

¹

6.2. Asia

A McKinsey report showed that over 700 million consumers use digital banking regularly in Asia (Barquin and Hv, 2015). India, Indonesia, Mongolia, Myanmar, Pakistan, and the Philippines are using digital financial services to increase access to finance for the poor and for women. Presently, there are over 775 million potential female users of mobile money in East Asia and Pacific. Regarding Fintech adoption, two Asian countries, China and India, have the highest Fintech adoption rate in the world at 87% and 87% respectively followed by Singapore according to a Ernest and Young global Fintech adoption index 2019 report.² A 2017 Asian Development Bank report show that digital financial services could increase the gross domestic product (GDP) of Asian economies by 14%, and has the potential to boost GDP to as high as 32% in Cambodia which is a much smaller market.³ Factors aiding the development of the digital finance ecosystem in Asia include an enabling framework for the provision of payments, the widespread use of e-money, and regulation that allows the use of agents by both banks and nonbank entities (World Bank, 2019). Some of the challenges facing the Asian digital finance ecosystem include regulatory arbitrage, regulatory uncertainty, incomplete schemes for the protection of customers, low financial literacy, and low technological literacy (World Bank, 2019).

6.3. Europe

Most of the investment in digital finance in Europe is currently invested in Fintech.⁴ The European Fintech ecosystem consists of 3,482 European ventures with 44% in the UK, 8% in Germany, 6% in Spain, 6% in France, 5% in Switzerland, 5% in Netherlands and the remaining 27% are spread across other European countries (Deloitte, 2020)⁵. Also, 5% of European Fintech deals accounted for around 65% of the total funding in the global Fintech sector according to a Finch Capital report.⁶ European Fintech companies raised a total of €3.52 billion in 2018. This number

² file:///C:/Users/xls/Downloads/ey-global-fintech-adoption-index-2019.pdf

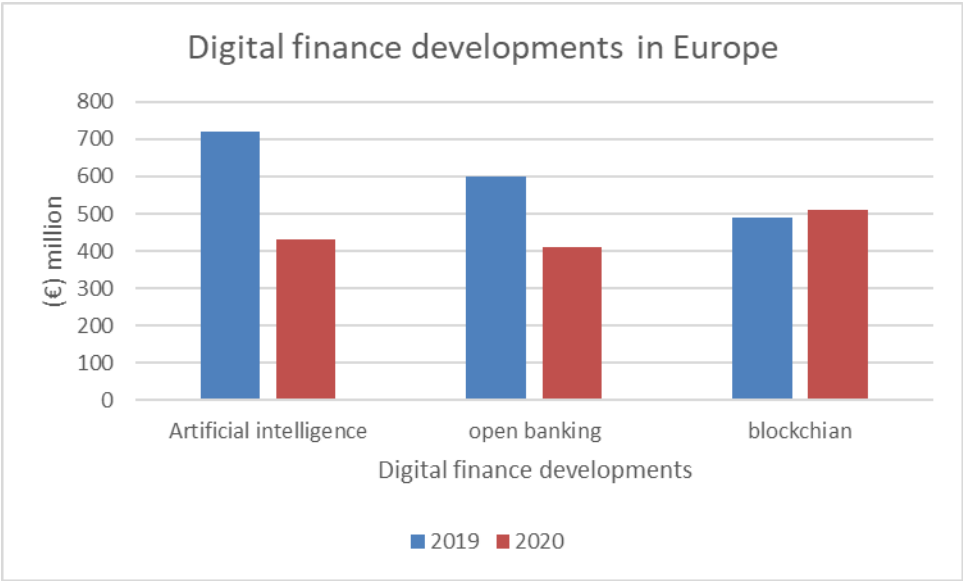
³ <https://www.adb.org/sites/default/files/publication/222061/financial-inclusion-se-asia.pdf>

⁴ <https://tech.eu/features/35066/european-fintech-report-2021/>

⁵ <https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/financial-services/deloitte-nl-fsi-fintech-report-1.pdf>

⁶ <https://www.siliconrepublic.com/start-ups/europe-fintech-growth-report-finch-2022>

increased by 150% to €8.81 billion in 2019 and to approximately €10 billion in 2020.⁷ Also, the amount of funding invested in artificial intelligence (AI) exceeded €750 million in 2019 and dropped to approximately €400 million in 2020 due to the pandemic while the total amount of funding invested in open banking systems amounted to over €400 million in 2019 and approximately €500 million in 2020 as shown in figure 1.



6.4. Africa

Digital finance began to gain inroads into Africa in early 2005 (AFR, 2021). As of 2021, there are over 514 Fintech companies offering digital financial services across the African continent (GDI, 2021)⁸. 98 of these companies have received over US\$100,000 and only 50 companies have received funding exceeding US\$1 million (GDI, 2021). Of the total investments made across the continent, 70% (US\$823m) of the investments are concentrated in payment solutions especially in mobile money payment solutions (AFR, 2021). In 2020 alone, Africa had 171 mobile money services, 562 million registered users, 161 million active accounts, 27.4 billion in transaction volume and US\$490 billion in transaction value (GSMA, 2021). West Africa and East Africa

⁷ <https://tech.eu/features/35066/european-fintech-report-2021/>

⁸ 2021 Good Data Initiative report

recorded the highest progress in mobile money adoption in the African continent according to data obtained from GSMA as shown in table 2. Some of the challenges faced by players in the African digital finance ecosystem are low fundraising, regulatory challenges, lack of understanding of the local digital finance market and finding talent.

Table 2. Africa Mobile Money 2020 statistics					
	Mobile money deployment live services	Number of registered accounts	Number of active accounts	Transaction volume	Transaction value (US\$)
Africa	171	562 million (+12% from 2019)	161 million (+18% from 2019)	27.5 billion (+15% from 2019)	495 billion (+23% from 2019)
West Africa	70	198 million (+19% from 2019)	47 million (+23% from 2019)	6.4 billion (+29% from 2019)	178 billion (+46% from 2019)
Southern Africa	14	11 million (+24% from 2019)	3 million (+28% from 2019)	284 million (+43% from 2019)	3.0 billion (+24% from 2019)
North Africa	14	14 million (+16% from 2019)	1 million (+22% from 2019)	77 million (+29% from 2019)	5.4 billion (+37% from 2019)
Central Africa	16	46 million (+2% from 2019)	16 million (+10% from 2019)	2.2 billion (+30% from 2019)	35.7 billion (+23% from 2019)
East Africa	57	293 million (+9% from 2019)	94 million (+16% from 2019)	18.6 billion (+10% from 2019)	273 billion (+11% from 2019)
(Source: GSMA 2021 report)					

7. The Future of digital finance

Having identified several advances in digital finance such as internet finance, fintech finance, open banking, embedded finance, decentralized finance and AI finance in section 3, a question that arises is where exactly is digital finance heading to? What is the future of digital finance? The future of digital finance is to create a digital environment that permits the offering of all kinds of financial product and services that can be customized and personalized to meet the unique needs of all users on a single digital platform and without requiring any form of human assistance or intermediary. In such an environment, a wide range of financial product and services such as insurance, banking, credit, investment and savings products will be offered on a single digital platform. Users will no longer need to have a different app for different financial services. Users

will have the option to customize financial services to meet their specific needs without requiring the assistance of a human agent. This will be made possible using digital identities, robotics, data analytics, machine learning and artificial intelligence (AI) solutions. Also, the future of financial risk management will change as AI and machine learning will change risk management in unprecedented ways. In risk management, AI and machine learning can be used to immediately identify any anomalies, patterns or unusual risks in financial transactions that are worthy of more human-centric investigation, and can also be used to make forecasts to aid decision making in financial risk management.

8. Areas for future research in digital finance

8.1. More research on how regulators can keep pace with emerging digital finance transformation

Regulators are generally not proactive in responding to rapid digital technology transformation in finance. This is largely due to the bureaucratic structure and processes in regulatory organizations. Regulators tend to take a long time to develop a new regulation for specific digital finance innovations and take a longer time to implement the regulation. By the time the regulation is ready to be implemented, the digital finance landscape has evolved to another emerging digital finance innovation and the already formulated regulation becomes outdated or obsolete. In a sense, regulators tend to lag behind in keeping up with emerging innovations in the digital finance ecosystem. Future research should suggest ways in which digital finance regulation can be more agile, dynamic and proactive. One idea is to adopt a principles-based digital finance regulatory framework rather than a rules-based regulatory framework. Another idea is that digital finance regulation should be designed to be technology-neutral so that digital finance regulations do not need to change as digital technology changes. It is also possible that greater collaboration between financial institutions and regulators is needed. Such collaboration can make it easier for financial institutions to inform regulators of new digital finance innovations as soon as they become aware of it. This will help regulators to keep pace with new innovations in the digital finance space so that they can issue regulations in a timely manner. Future research

should explore additional ideas or suggestions on how regulators can keep pace with emerging digital finance transformation.

8.2. More research on user information security and compliance

It is possible that future digital finance innovations will collect additional user data that is sensitive and very confidential to users such as users' digital identification number. Existing digital finance innovations, such as internet banking applications, mobile money applications, central bank digital currency tokens or wallets, also collect sensitive and confidential data of users. As a result, there will be concerns about the security of users' sensitive information, and compliance with existing data privacy rules. The dilemma in data security and privacy depends on the need to collect as much information as possible to properly identify a legitimate user of a digital finance application, and the need to protect the sensitive information of users stored on digital databases or stored in the cloud. Future research studies should investigate ways to increase user data security and strengthen compliance policies.

8.3. More research on how to deal with bias caused by bad data

Machine learning and artificial intelligence solutions will undoubtedly play an important role in the future of digital finance. The outcome of machine learning and artificial intelligence solutions will depend on the data that is fed into the system. However, the nature and structure of data (both financial and non-financial) that is fed into AI-based DFS systems may reinforce social, gender and racial biases rather than eliminate them especially when bad data is unintentionally fed into AI-based DFS systems. Bad data, in the context of human equality, refers to any data whose structure reinforces a social bias, gender bias or racial bias. There is a need to find ways to re-invent AI-based data collection and processing systems in ways that enable such systems to detect bad financial and non-financial data before processing it so that such systems can reject the data altogether until a human agent restructures the data to ensure it has no bias. This will ensure that any financial or nonfinancial data whose structure reinforces existing social and gender bias are rejected by AI-based data collection and processing systems. Future research can suggest innovative ways to re-invent AI-based data collection and data processing systems so

that they can identify biases in data structure and escalate data anomalies to a human agent for corrections.

8.4. More research on how to deal with algorithmic bias

This is related to the previous point. Algorithmic bias or artificial intelligence (AI) bias occurs when an algorithm produces results that are systemically prejudiced due to erroneous assumptions in the machine learning process (Lin, 2019). Erroneous assumptions in the machine learning process could lead to decisions that are systematically unfair to a large group of people. The implication for digital financial services is that it could lead financial institutions to charge relatively low interest rates to Caucasian borrowers while charging relatively high interest rates to borrowers from an ethnic minority group. Also, algorithmic bias could restrict access to financial services to certain group of customers while favouring more access to finance to specific group of customers. There is a need to find ways to eliminate or reduce erroneous assumptions that lead to algorithmic bias. Future research studies can identify ways to eliminate or reduce algorithmic bias.

8.5. More research is needed on combining a risk-conscious culture with a higher risk appetite for digital finance transformation

More research is needed on how risk-conscious financial institutions can take on high risk in digital transformation without breaching existing risk limits. Most financial institutions have a risk-conscious culture that limit their ability to take high risk in digital transformation (Deloitte-IIF, 2020). Since most financial institutions' processes and operating model are designed to protect against a number of risks (Deloitte-IIF, 2020), the risk management system of financial institutions may flag investment in digital transformation as a high risk activity because digital transformation requires some degree of uncertainty and experimentation. Therefore, proceeding to undertake such transformation will be at the discretion of the board of directors. Also, there might be a need to modify the risk management system of financial institutions in a way that ensures that the risk consciousness of financial institutions do not hinder financial institutions from making critical digital transformation as the need arises.

9. Summary and conclusion

This paper presented a concise review of the existing digital finance research in the literature, and highlight some of the developments in digital finance around the world. The paper reached several conclusions. Firstly, it showed that digital finance has become an important part of modern finance and the major application of digital finance can be found in Fintech, embedded finance, open banking and decentralized finance, central bank digital currencies, among others. Secondly, it identified some international determinants of digital finance which includes the need for efficiency in financial services delivery, the need to achieve the United Nations sustainable development goals using existing digital technologies, the need to increase financial inclusion through digital financial inclusion and the need for efficient payments and payment settlement finality. The paper also finds that digital finance research is growing fast, and many studies have investigated contemporary issues in digital finance that are relevant for policy and practice. Regarding the digital finance developments around the world, the paper showed that the Fintech and mobile money industries have been the largest beneficiary of investments in digital finance with the total number of users of mobile money services surpassing 1 billion globally. Also, the paper predict that the future of digital finance is to create a digital environment that permits the offering of all kinds of financial product and services that can be customized and personalized to meet the unique needs of all users on a single digital platform and without requiring any form of human assistance or intermediary. The paper then suggest some areas for future research which include the need for more research on how regulators can keep pace with emerging digital finance transformation, the need for more research on user information security and compliance, the need for more research on how to deal with bias caused by bad data, the need for more research on how to deal with algorithmic bias, and the need for more research on how to combine a risk-conscious culture with a higher risk appetite for digital finance transformation.

In conclusion, digital finance transformation is likely to take different forms in different parts of the world due to differences in technology advancement, differences in the willingness to embrace change, differences in policy and regulatory support for digital finance transformation, and differences in understanding the risks associated with new digital finance innovation. In some countries, financial institutions and Fintech players will take a conservative approach towards digital finance transformation. In other countries, financial institutions and Fintech

players may take a bold approach to keep pace with new digital finance transformation in order to gain some first-mover advantages – a move that could make regulators lag behind. Such decisions, however, need to be made with an in-depth understanding of the risks associated with new digital finance innovations and after obtaining the necessary regulatory approvals. While the role of banks in the future of digital finance is still uncertain, it is certain that banks will face increasing pressure to re-invent themselves to remain relevant, as such, they will have to choose to innovate or perish.

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