

Financial stability with digital finance innovation: a BigQuery-based empirical investigation

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Abstract

This study empirically explores how digital financial innovations (DFIs) drive financial stability with a BigQuery-based approach in measuring DFIs and a global analysis covering 74 countries in the 2002 – 2022 period. Specifically, this study measures DFIs by searching for patents related to DFIs, which are evaluated based on the abstract/title of the patent applications. The empirical result shows that DFIs are positively associated with financial stability. Furthermore, with the BigQuery-based approach, this study is also able to explore how different types of DFIs impact the stability of the financial system. Results show that DFIs in Payment, AI and Big Data, and Security and Regtech are significant and positively affect financial stability, while DFIs in Digital Banking and Blockchain technology lack statistical significance. Crucially, DFIs in AI and Big Data appear to have the most pronounced impact. The research findings are reinforced by multiple robustness checks, including endogeneity analysis with IV-2SLS, isolation of temporal shocks, non-linearities checks. Additionally, the heterogeneity analysis also shows that developing countries may benefit more from the stabilizing impacts of DFIs. From these findings, practically valuable implications can be drawn, shedding light on how to leverage DFIs to yield the highest effectiveness.

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1. Introduction

Characterized by global financial crisis, political polarization, the pandemic, global trade conflicts, and so on, uncertainty has been recognized as the main theme of the beginning of the 21st century. However, contrary to common beliefs, the financial system is more than just a facade but it plays a critical role in transmitting and amplifying shocks and systemic risks (Zanfack et al., 2024). Therefore, maintaining financial stability has been of paramount importance, profoundly affecting all aspects of the economy, shielding against external shocks or accumulating imbalances (Bashir & Yu, 2020; Elsayed et al., 2023; Hussain & Bashir, 2020; Kulu et al., 2024). Moreover, financial stability is especially important to developing countries (Nguyen, 2024).

Meanwhile, due to the rapid development and integration of digital technologies into the financial sector, digital financial technologies or innovations (DFIs) are expected to foster positive changes, if not a complete paradigm shift, to the financial system. DFIs can be defined as a new financial industry that utilizes

digital technology to enhance financial performance by introducing innovations in financial services, such as Internet banking, mobile payments, crowdfunding, peer-to-peer (P2P), Robo-Advisory, online identification (Arner et al., 2022; Schueffel, 2016). Despite the lack of a unified definition of digital finance, it is widely recognized that DFIs encompasses all products, services, technology, and/or infrastructure and enable corporations or individuals to easily access financial services via the digital platform (Ozili, 2018).

The benefits of DFIs are manifold, ranging from a greater extent of financial inclusion and the expansion of financial services (World Bank, 2014), to the better management and facilitation of financial activities (Manyika et al., 2016; Ozili, 2018), all contributing to the financial stability of an economy. Nevertheless, an evidence gap persists as there have also been studies pointing out the dark side of digital finance. For instance, the widespread adoption of DFIs may disrupt banking performance and financial stability (Buchak et al., 2018), amplify corporate debt risks (Suhrab et al., 2026). Hence, whether DFIs actually benefit the financial sector and the economy by ensuring financial stability remains an empirical question. Besides this evidence gap due to mixed results, a methodological gap also persists, as there has been a controversy on how to measure DFIs. While some utilize digital infrastructure metrics to evaluate the digital finance technologies, such as mobile phone subscriptions per 100 people or individuals using the Internet (Antwi & Kong, 2023), some use the number of new FinTech companies established in a year (Nguyen & Dang, 2022). However, the study argues that these metrics are not sufficient to fully capture the development of DFIs in general, not to mention capturing different types of DFIs. Specifically, besides ATM, there is a large number of other digital finance technologies that can outperform this technology. Moreover, counting new FinTech firm formation may overlook innovations generated within incumbent banks or foreign tech firms.

Thus, this study is conducted to examine the effects of DFIs on financial stability based on a global analysis covering 74 economies from 2002 to 2022. More specifically, to measure the development of DFIs, this research adopts an output-based approach and the BigQuery technique to collect data on DFI-related patents. Thereby, this study also manages to evaluate the impacts of not only the general DFI but also different types of DFI.

The remainder of the research is constructed as follows. The second section reviews related literature and constructs the theoretical framework. The third section outlines methods employed for empirical investigation. The fourth section presents empirical results and discussion. The last section gives implications and concluding remarks.

2. Literature Review

Throughout the development of the financial sector, critical limitations of traditional bank models have been revealed, for instance, the lack of interaction with customers, insufficient post-transaction tracking systems, limiting their capability to meet financial needs and requirements (Liang et al., 2025). Consequently, the banking industry has undergone a critical transformation (Shabir et al., 2024). Theoretically, with the emergence of digital technologies, banks are capable of offering new financial products and services, or approaching new customer segments, making better credit decisions, analyzing customer data more efficiently, yielding higher profitability and risk-taking capacity (Antwi & Kong, 2023; Liang et al., 2025). On the other hand, it is also argued that this transformation can threaten banks' stability due to the lack of expertise (Antwi & Kong, 2023). Therefore, a wide range of empirical studies has investigated the link between DFIs and the stability of the financial system.

Regarding the positive impact of DFIs, the early work of DeYoung (2005) shows that the Internet-based delivery channel of banks can produce positive outcomes if sufficiently large scale is attained and strong management practices are implemented. By employing a similar analytical framework and methodology within the context of European banks, Delgado et al. (2007) reveal that Internet-based banking can benefit from scale and experience efficiency, contributing to higher profitability and stability. As a supporting explanation for the role of digital technologies, it is also pointed out that improved information availability and open contract enforcement can stabilize the financial system, especially in low-income countries (Demirgüç-Kunt et al., 2008; Djankov et al., 2007). As a more recent effort, Scott et al. (2017) highlight that the adoption of SWIFT can raise banking performance based on the data of 6848 banks in Europe and the Americas. By using ICT diffusion, adoption, and infrastructure (e.g., ATM penetration), Del Gaudio et al. (2021) show the positive link between ICT advancement and banks' performance, which can be explained by the shift to digital payment services. There are also studies explaining the positive effects of digital finance through the role of financial inclusion (Banna & Alam, 2021; Liang et al., 2025). Hence, based on this argument, Liang et al. (2025) measure digital finance development with the Digital Inclusive Finance Index. Moreover, the application of digital technologies can offer more accurate recording and supervision of financial transactions (Hannig & Jansen, 2010; Morgan & Pontines, 2014). Therefore, this will encourage financial deregulation, especially in developing countries, allowing higher profitability and stability for the banking sector (Scott et al., 2017). Additionally, it has also been revealed that the influence of DFIs may vary depending on different types of proxies. Specifically, Antwi and Kong (2023) report that while mobile phone subscriptions cause a negative impact on financial stability, internet usage shows a favorable impact.

Nevertheless, digital financial technologies also introduce new threats, leading to opposite findings. Digital financial products, such as fintech and peer-to-peer lending, has been proven to be disruptive to banking performance and financial stability (Buchak et al., 2018; Tang, 2019). In particular, digital banking activities may amplify the total risks of banks, namely, strategic risks, operational risks, and legal risks (Antwi & Kong, 2023; Ozili, 2018). For instance, digital banking can result in the proliferation of non-performing loans and emerging threats, such as data theft (Vives, 2019). Contrary to the deregulation effect (Scott et al., 2017), digital finance may contrarily lead to stricter regulations, or sometimes it may cause higher risks due to insufficient regulation (García & José, 2016).

From the literature review, it is evident that the extant literature remains controversial. While this empirical controversy may stem from the research settings, the heterogeneity due to the use of different proxies (Antwi & Kong, 2023) shows that the measurement of DFIs can also influence the empirical findings. Therefore, to address the evidence gap and the methodological gap relating to the measurement of DFIs, this study is conducted to explore the link between DFIs and financial stability. Moreover, from the extant literature, it is apparent that different types of DFIs can affect financial stability heterogeneously. For instance, while the application of the SWIFT can benefit the banking sector (Scott et al., 2017), peer-to-peer lending affects oppositely (Buchak et al., 2018; Tang, 2019). Therefore, the two following hypotheses are proposed for empirical investigation:

Hypothesis 1: DFIs are positively associated with financial stability.

Hypothesis 2: The positive impacts of DFIs on financial stability vary depending on different types of DFIs.

3. Data and Methodology

3.1 Research Model

To empirically examine how DFIs influence financial stability, this research constructs the following empirical research model:

$$zscore_{i,t} = \beta_0 + \beta_1 dfi_{i,t} + \beta_2 Controls_{i,t} + \varepsilon_{i,t}$$

Where: $zscore_{i,t}$ is the dependent variable, representing the levels of financial stability of country i in year t ; $dfi_{i,t}$ is the main explanatory variable, representing the levels of development of DFIs; $Controls_{i,t}$ is the set of control variables; and $\varepsilon_{i,t}$ is the error term.

3.2 Variables and Data

3.2.1 Dependent Variable: Financial Stability

The banking z-score is widely adopted in empirical literature to measure financial stability due to its objective, distribution-free ability to capture banks' deviation from insolvency (Liang et al., 2025; Oanh et al., 2023). The z-score is calculated as follows:

$$zscore = \frac{ROA - (Equity)/(Total Assets)}{\sigma(ROA)}$$

Data for national-level banking z-score is from the Global Financial Development (GFD) Database of World Bank (WB).

3.2.2 Main Independent Variable: Digital Finance Innovation

From the extant literature, the digital infrastructure appears to be the most commonly-used proxy for digital finance, such as mobile subscriptions or internet usage (Antwi & Kong, 2023) or ATM penetration (Del Gaudio et al., 2021). However, this approach in measuring DFIs might not fully capture the development of DFIs. For instance, besides ATM, there is a large number of other digital finance technologies that can outperform this technology. Therefore, this study employs a different approach based on patent data. Despite a wide range of innovation proxy, patent data is the most commonly-used, allowing scholars to assess innovation activities quantitatively and qualitatively (Hasan & Tucci, 2010; Tu & Nguyen, 2026).

Therefore, to determine patents that are DFI-related, the study employs a BigQuery-based approach based on the Google Patents Public Data database. The database directly indexes official, public-domain data from over 100 patent offices worldwide, for example, USPTO, EPO, WIPO. The data contains all information related to a patent application, including title and abstract. Hence, this study performs a granular keyword mapping. A patent is counted as DFI-related if its title and/ or its abstract contain keywords relating to DFI. Moreover, the list of keywords is also clustered into different types of DFI, allowing the study to quantify the number of each type of DFI. In this study, DFI is classified into five types: DFIs in Payment ($dfi_payment$); DFIs in Blockchain technology ($dfi_blockchain$); DFIs in AI and Big data ($dfi_aibigdata$); DFIs in Digital banking ($dfi_digibank$); and DFIs in Security and RegTech ($dfi_regtech$). The list of keywords is shown in Table A1.

3.2.3 Control Variables

Following the work of Oanh et al. (2023), the set of control variables in the model of this research includes: economic size (gdp), inflation rate (infla), domestic credit (credit), population size (pop), lending interest rate (int), and gross capital formation (cap).

Table 1. Variables description

Variable	Description	Data source
zscore	The banking z-score, reflecting the probability of default of a country's commercial banking system	GFD (WB)
dfi_total	Natural logarithm of (the total number of patents related to DFIs in general + 1)	Global Patent Offices
dfi_payment	Natural logarithm of (the total number of patents related to DFIs in Payment + 1)	
dfi_blockchain	Natural logarithm of (the total number of patents related to DFIs in Blockchain technology + 1)	
dfi_aibigdata	Natural logarithm of (the total number of patents related to DFIs in AI and Big Data + 1)	
dfi_digibank	Natural logarithm of (the total number of patents related to DFIs in Digital Banking + 1)	
dfi_regtech	Natural logarithm of (the total number of patents related to DFIs in Security and RegTech + 1)	WDI (WB)
gdp	Natural logarithm of GDP per capita	
infla	Inflation rate (GDP deflator) (%)	
credit	Domestic credit to private sector (% of GDP)	
pop	Natural logarithm of total population	
int	Lending interest rate (%)	
grosscap	Gross capital formation rate (% of GDP)	

Source: Developed by authors.

4. Results And Discussion

4.1 Descriptive Statistics

Table 2 presents the descriptive statistics of the studied variables. Regarding the dependent variable, the variation and the presence of negative values of the z-score indicate that the dataset captures both stable systems and periods of severe banking distress. Regarding the DFIs, dfi_total shows a right-skewed distribution with a mean of 0.7359 and a larger standard deviation of 1.5222, demonstrating a gap between nations in developing DFI. This asymmetry is further reflected in the disaggregated types, where consumer-oriented DFIs, such as like dfi_payment and dfi_blockchain are more mature than those advanced tools like dfi_aibigdata, dfi_digibank, and dfi_regtech. Therefore, these heterogeneous levels of development can drive financial stability inconsistently, justifying the examination of H2.

Table 2. Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
zscore	1,363	15.2409	10.0412	-0.3259	66.27
dfi_total	1,456	0.7359	1.5222	0	8.5924
dfi_payment	1,456	0.547	1.2652	0	6.708
dfi_blockchain	1,456	0.4859	1.2535	0	8.4173
dfi_aibigdata	1,456	0.1346	0.4964	0	4.4773
dfi_digibank	1,456	0.0768	0.3594	0	3.3672
dfi_regtech	1,456	0.1249	0.4889	0	4.5951
gdp	1,456	9.4184	1.1950	5.7737	11.8127
infla	1,456	8.7516	57.9715	-18.8992	1890.394
credit	1,228	77.8813	48.1915	0.1861	304.575
pop	1,456	16.2476	1.7428	10.7380	21.0684
int	1,456	13.5239	8.9929	0.5	89.5537
grosscap	1,393	22.6112	5.0334	10.9704	53.2106

Source: Developed by authors.

4.2 Baseline Results

Model (1) from Table 3 presents the baseline estimation of the research model. Importantly, the variable of DFIs (dfi_total) demonstrates a statistically significant and positive coefficient ($\beta = 0.332$; p-value = $0.070 < 0.1$), confirming H1 posited in the study. The coefficient implies that with every 1% increase in the total number of DFIs, z-score will increase by 0.00332 units, indicating higher financial stability and lower risk of insolvency. However, compared to the standard deviations of the z-score, it is evident that digital finance technologies have a positive but very gradual impact on stabilizing the banking system. Regarding control variables, economic growth (gdp) and gross capital formation (grosscap) are both significant promoters of financial stability, with statistical significance and positive coefficients. However, higher domestic credit (credit) and higher lending interest rate (int) can be detrimental to the stability of the financial system.

Moreover, to address concerns that there can be potential lagged effects, where DFIs may require time for spreading and being adopted, the first-order lagged variable of DFIs (L.dfi_total) is included in Model (2) of Table 3. Hence, it is clear that the positive effects of DFI are even more pronounced in the long-run ($\beta = 0.384$; p-value < 0.05).

Table 3. Baseline estimation results

	(1)	(2)
	FE	FE
	zscore	zscore
dfi_total	0.332* (0.173)	
L.dfi_total		0.384** (0.183)
gdp	-0.006 (0.383)	0.078 (0.398)
infla	-0.007 (0.011)	0.003 (0.012)
credit	-0.011** (0.005)	-0.013** (0.005)
pop	-0.002 (0.058)	-0.022 (0.058)
int	-0.027** (0.012)	-0.025** (0.012)
groscap	1.500*** (0.563)	1.013* (0.568)
_cons	-17.208 (11.052)	-6.382 (11.082)
Country FE	Yes	Yes
Year FE	Yes	Yes
N	1363	1276
R2	0.101	0.103

Source: Developed by authors.

Note: * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01. Standard errors are presented in parentheses ().

4.3 Disaggregated Analysis

As DFIs are multidimensional and encompass a wide range of applications, this study also conducts a disaggregated analysis to explore how different types of DFIs impact financial stability. Five main types are identified, including: DFIs in Payment (dfi_payment); DFIs in the Blockchain technology (dfi_blockchain); DFIs in AI and Big Data (dfi_aibigdata); DFIs in Digital Banking (dfi_digibank); and DFIs in Security and RegTech (dfi_regtech). Thus, the disaggregated results are shown in Table 4. Accordingly, it is evident that while DFIs in Payment, DFIs in AI and Big data, and DFIs in Security and RegTech positively contribute to higher financial stability, other types, including DFIs in Blockchain technology and DFIs in Digital banking, lack of statistical significance. Moreover, by comparing the coefficient, it is apparent that DFIs in AI and Big data have the most pronounced impact, such that every 1% increase in the total number of this type of DFIs, the z-score will increase by 0.0133 units. Hence, this heterogeneity has supported H2. The significance and coefficient sign of other control variables are still preserved.

Table 4. Disaggregated estimation results

	(1)	(2)	(3)	(4)	(5)
	zscore	zscore	zscore	zscore	zscore
dfi_payment	0.597** (0.240)				
dfi_blockchain		0.177 (0.159)			
dfi_aibigdata			1.330*** (0.368)		
dfi_digibank				0.322 (0.409)	
dfi_regtech					1.017*** (0.385)
gdp	-0.078 (0.385)	0.092 (0.378)	-0.078 (0.379)	0.110 (0.378)	0.004 (0.379)
infla	-0.007 (0.011)	-0.007 (0.011)	-0.007 (0.011)	-0.006 (0.011)	-0.006 (0.011)
credit	-0.011** (0.005)	-0.011** (0.005)	-0.012** (0.005)	-0.010** (0.005)	-0.011** (0.005)
pop	0.004 (0.058)	-0.007 (0.058)	0.002 (0.058)	-0.007 (0.058)	-0.002 (0.058)
int	-0.028** (0.012)	-0.026** (0.012)	-0.025** (0.011)	-0.026** (0.012)	-0.026** (0.012)
groscap	1.620*** (0.561)	1.489*** (0.568)	1.655*** (0.560)	1.577*** (0.562)	1.565*** (0.561)
_cons	-19.308* (10.950)	-17.661 (11.162)	-19.888* (10.917)	-19.693* (10.977)	-18.581* (10.956)
Country FE	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes
N	1363	1363	1363	1363	1363
R2	0.102	0.099	0.107	0.099	0.103

Source: Developed by authors.

Note: * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01. Standard errors are presented in parentheses ().

4.4 Robustness Checks

4.4.1 Endogeneity Analysis

Due to potential endogeneity concerns, this research ensures the robustness of the findings with the endogeneity analysis, specifically focusing on the simultaneity issue. First, to address the simple simultaneity issue, the research adds the first-order lag of all independent variables, treating all independent variables as predetermined. From Model (1) of Table 5, it is evident that the sign and significance of the coefficient indicated by DFIs stay unchanged. Second, to further address the endogeneity issue, the Instrumental Variable–Two Stage Least Squares (IV-2SLS) is employed. For the IV, the study argues that the number of citations of

DFI-related patents can serve as an IV. Theoretically, a higher citation rate means that preceded innovations are high-quality and contain strong knowledge spillovers. This will pave the way for sequential innovations, resulting in the reverse causality issue. Statistically, the adequacy of this IV is also supported as the Kleibergen-Paap rk LM statistic and Wald F statistic are both statistically significant. The estimation results using the IV-2SLS approach show that DFIs remain positively associated with financial stability. Overall, it is evident that the robustness of the findings is confirmed when accounting for the endogeneity issue.

Table 5. Endogeneity analysis results

	(1)	(2)
	Lag of all indep. var.	IV-2SLS
	zscore	zscore
dfi_total	0.644*** (0.239)	1.357** (0.718)
Controls	Yes	Yes
Country FE	Yes	Yes
Year FE	Yes	Yes
N	1175	1125
R2	0.143	0.001
Kleibergen-Paap rk LM statistic (p-value)		0.007
Kleibergen-Paap rk Wald F statistic		79.282
Stock-Yogo critical values (10%)		16.38
Hansen J test (p-value)		-

Source: Developed by authors.

Note: * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01. Standard errors are presented in parentheses ().

4.4.2 Controlling for Temporal Shocks

As the temporal scope of this study spans from 2001 to 2022, this also includes structural shocks that may influence financial stability on the global scale, most notably the global financial crisis (2008-2009) and the COVID-19 pandemic (2020-2021). On one hand, the global financial crisis represents a severe, systemic breakdown of traditional banking systems. On the other hand, the COVID-19 pandemic, despite having promoted the adoption of DFIs, caused critical volatility in bank stability, which was directly driven by unprecedented economic shutdowns, extraordinary central bank liquidity injections as responses to the pandemic. Therefore, to ensure the robustness and consistency of the results, the author dropped these two periods from the statistical estimation. Nonetheless, the positive impacts of DFIs are still preserved and remain significant, demonstrating the robustness and consistency of the findings.

4.4.3 Checks for Non-Linearities

Due to concerns surrounding whether DFIs non-linearly drive financial stability, such that while low to moderate levels of DFIs development can benefit the financial system, but excessive DFIs application can yield drawbacks, a non-linearities check is recommended. Thus, this study also adds the quadratic form of the primary variable. However, the estimation results show no statistical significance of the non-linear impact, ensuring the robustness of the linearly positive influence of DFIs on financial stability.

4.4.4 Heterogeneity Analysis

As the sample of this study includes countries at various stages of development, to unravel the heterogeneous effects of DFIs on financial stability across different levels of development, this research also conducts a subsample estimation analysis. From the results in Table 6, it is evident that while developed countries see no significant benefit from DFIs, digital finance technologies significantly improve the financial stability of developing countries. Therefore, the divergence is evidenced, yielding interesting implications.

Table 6. Heterogeneity analysis results

	(1)	(2)
	Developed	Developing
	zscore	zscore
dfi_total	-0.173 (0.229)	0.813*** (0.250)
Controls	Yes	Yes
Country FE	Yes	Yes
Year FE	Yes	Yes
N	823	540
R2	0.183	0.152

Source: Developed by authors.

Note: * p-value < 0.1; ** p-value < 0.05; *** p-value < 0.01. Standard errors are presented in parentheses (). The country classification follows the official World Bank Income Classification system, which categorizes economies based on Gross National Income (GNI) per capita.

4.5 Discussion

With the BigQuery-based approach for measuring DFIs, this study conducts an empirical global analysis covering 74 countries from 2002 to 2022 to explore the link between DFIs and the stability of the financial system. The empirical results yield critical findings as follows.

First, the positive stabilizing effects of DFIs on the financial system are confirmed, such that every 1% increase in DFI-related patents can result in an increase by around 0.00332 units in terms of the z-score of banks. This finding is aligned with the majority of previous studies (Banna & Alam, 2021; Del Gaudio et al., 2021; DeYoung, 2005; Liang et al., 2025; Scott et al., 2017). Theoretically, this positive link can be explained by several mechanisms. For instance, DFIs can promote financial stability through the role of improved information availability and open contract enforcement (Demirgüç-Kunt et al., 2008; Djankov et al., 2007), or through the role of better financial inclusion (Banna & Alam, 2021; Liang et al., 2025). From the perspectives of regulators, DFIs can allow the authorities to have better recording and supervision of financial transactions (Hannig & Jansen, 2010; Morgan & Pontines, 2014). Hence, this study provides empirical evidence challenging the stream of literature asserting that DFIs may dampen financial stability (Buchak et al., 2018; Tang, 2019).

Second, as the BigQuery-based approach allows the classification of DFI-related patents, the study also examines how different types of DFIs drive financial stability. The results illustrate substantial heterogeneity. Specifically, while DFIs in Payment, AI and Big Data, and Security and Regtech are statistically

significant and positively drive financial stability, DFIs in Digital Banking and Blockchain technology lack statistical significance. This reveals a practical reflection that: the development of digital banking and blockchain technology in finance is insufficient to support a better financial system. While the benefits of digital banking and blockchain are evident, one of the possible causes of this insignificance can be the lack of adequate regulatory frameworks. While digital finance may enable deregulation (Scott et al., 2017), digital finance can also contrarily cause higher risks due to insufficient regulation (García & José, 2016). Thus, this could create regulatory loopholes for unlawful operations, such as data theft, market manipulation, cyber fraud, or online money laundering, which can critically dampen financial stability. For instance, according to the Cybercrime Report, digital fraud attacks have risen by 17% since 2025. Hence, this necessitates improving the regulatory framework and the better management of DFIs in digital banking and blockchain. On the other hand, DFIs in AI and Big Data appear to yield the highest effectiveness in stabilizing the financial system. AI and Big Data can optimize financial stability by reducing the information asymmetry through real-time data processing, thereby improving credit scoring precision and loan portfolio monitoring of banks. Hence, this specifically challenges the view that AI innovations in finance can amplify risks persisting in the financial markets (OECD, 2023).

5. Conclusion

In essence, this study has provided a comprehensive global analysis of how DFIs influence financial stability. Utilizing the novel BigQuery-based patent tracking approach to capture the DFI development, the empirical findings demonstrate that DFIs are positively associated with systemic financial stability. However, this link is not uniform across all types of technology. Granular multi-dimensional analysis reveals that DFIs in Payment, Security and Regtech, and especially AI and Big Data significantly contribute to the higher stability of the financial system, with AI and Big Data exerting the most pronounced stabilizing impact. Conversely, innovations within Digital Banking and Blockchain technology show statistical insignificance. These core findings remain robust when subject to robustness checks, including IV-2SLS endogeneity analysis, the isolation of temporal shocks, and non-linear specifications. Moreover, heterogeneity analysis indicates that developing economies stand to gain a more substantial stabilizing dividend from expanding digital financial architectures than advanced economies.

This paper makes vital contributions to the extant literature as follows. First, it addresses a persistent measurement challenge by moving beyond infrastructure-based proxies, introducing a text-mining methodology based on data. Second, by deconstructing DFIs into five distinct sub-dimensions, this study provides empirical nuance to the ongoing debate on whether digitalization may stabilize the financial market or amplify the existing risks, showing that different types of DFI can have different impacts, necessitating a multidimensional approach when managing DFIs in the practical setting.

Based on these findings, critical implications can be drawn. First, prioritizing strategic AI and Big Data innovations in finance. Given that innovations in AI and Big Data possess the most pronounced capability of stabilizing the financial system, regulatory frameworks should actively incentivize commercial banks to absorb these technologies. For instance, providing targeted tax incentives for technological R&D, and reducing capital adequacy requirements for commercial banks, training digital finance talents in terms of both R&D and management. Second, the lack of statistical significance observed in blockchain and digital banking DFIs underscores a regulatory gap. Policymakers should expand the deployment of financial regulatory sandboxes to allow these early-stage or volatile technologies to mature. Moreover, as digital financial products and

services can transcend beyond borders, international cooperation in designing regulatory framework and management of these financial technologies should be promoted as well. Third, digitalizing the management of the financial system with Security and Regtech innovations significantly. This will help to ensure better management and coordination capability of regulators and banks. Last, developing countries should prioritize tech-driven financial strategies. As developing nations can benefit from greater stabilizing effects from DFIs, these nations should design policies and mechanisms specifically for the development and implementation of DFIs. For example, setting up open innovation clusters and regulatory sandboxes. More importantly, to ensure that DFIs can yield the highest effectiveness, these nations should, in parallel, develop the digital infrastructure, providing people with the necessary and sufficient tools to access digital financial products and services.

However, the BigQuery-based text-mining approach, restricting keyword searches strictly to patent titles and abstracts may also introduce methodological trade-offs. While titles and abstracts contain the core inventive concepts of patent application, this approach may omit relevant innovations whose DFI functionality is described exclusively within the full text or patent claims. In addition, there might be also other innovations that may not originally designed for the digital finance domain but still function as an innovative solution to this sector. Hence, future research could expand upon this methodology by employing natural language processing (NLP) across full patent texts to further capture the depth of DFIs.

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Declaration of the Use of Generative AI

The author did not use any generative AI tools or AI-assisted technologies.

Data Availability Statement

Data is available on request.

Conflicts of Interest

The author declares no conflict of interests.

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Appendix A

Table A1. List of keywords related to DFIs

Type of DFIs	List of keywords
Payment	digital payment, mobile payment, e-wallet, electronic wallet, contactless payment, p2p payment, peer-to-peer payment, cross-border payment, digital currency, cbdc, central bank digital currency, mobile wallet, nfc payment, pos terminal, tokenized payment, rtgs, clearing house settlement, electronic fund transfer, eft, qr code payment, remittance technology, digital fiat, payment gateway, stored value card, merchant service automation
Blockchain technology	blockchain, distributed ledger, dlt, smart contract, cryptocurrency, bitcoin, ethereum, decentralized finance, defi, tokenization, digital asset, hyperledger, crypto wallet, initial coin offering, ico, security token, stablecoin, proof of stake, proof of work, decentralized exchange, dex, non-fungible token, nft, consensus mechanism, crypto asset, liquidity pool, yield farming
AI and Big Data	financial machine learning, robo-advisor, algorithmic trading, credit scoring model, automated underwriting, financial big data, predictive analytics in finance, high frequency trading, hft, financial neural network, financial data mining, portfolio optimization algorithm, sentiment analysis finance, quantitative trading, quant trading, robo-advisory, market microstructure algorithm, alternative data finance, automated market maker, amm, financial NLP, natural language processing finance
Digital Banking	digital banking, neo-banking, neobank, open banking, crowdfunding, p2p lending, peer-to-peer lending, marketplace lending, insurtech, insurance technology, challenger bank, banking api, embedded finance, digital microfinance, virtual bank, internet-only bank, equity crowdfunding, alternative credit scoring, social lending, digital wealth management, micro-lending platform
Security and RegTech	financial fraud detection, anti-money laundering, aml compliance, know your customer, kyc technology, regtech, regulatory technology, biometric authentication finance, biometric payment, transaction monitoring, financial cryptography, secure electronic transaction, cybersecurity in finance, financial cyber-risk, identity verification finance, fraud prevention financial, risk assessment algorithm finance, suptech, supervisory technology, anti-fraud system, financial data privacy

Source: Developed by authors.