FinTech and Financial System Stability in South Africa

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Abstract

We examine the impact of FinTech formations on the default risk of incumbent financial institutions in South Africa and find that the development of FinTech startups reduces bankruptcy risk, credit risk and stock return volatility of banks and other financial institutions. FinTech startup formations is also associated with improvement in incumbent institutions' performance. Further analysis shows that the risk reduction effect of FinTech is more pronounced in small banks than large banks. In fact, large banks experience initial increase in risk from FinTech development. Overall, our results are consistent with the assertion that FinTech improve the efficiency of risk management and consequently reduce default risk of incumbent financial institutions. However, the relationship is non-linear, suggesting that the initial collaboration which leads to a reduction in default risk can turn to increased competition as more FinTech startups enter the market. Given the central role of financial institutions in the nation's development, the growth of FinTech firms might to some degree counteract the too systemic-to-fail phenomenon. From a policy standpoint, efforts to promote more collaboration should be encouraged but regulators should still be cautious of potential systemic risk which could result from possible data breach.

JEL Codes: G32; G21; G23; Q55

Keywords: FinTech, Financial Institutions, Default risk, Performance, Financial Stability, South Africa

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1. Introduction

FinTech is reshaping the banking sector worldwide, and the financial system in South Africa one of the most developed markets in the developing world (World Economic Forum, 2016) has not been spared of the FinTech revolution. The mobile money revolution has improved access to finance and shortened the distance and time for accessing financial services. The World Bank reports that Sub-Saharan Africa is by far the region with the highest adoption of mobile money account (Demirgüç-Kunt et al., 2018). With their strong technology-driven offerings, FinTech firms have redefined the way financial institutions operate their business, the products and services they offer, and the client bases they serve. While there are benefits associated with financial innovation and FinTech development, there are also serious challenges that FinTech presents to South African banks which can lead to an increase in default risk. Financial innovations developed by FinTech firms benefit customers in the delivery of existing products by making banking operations available at all times and at a cheaper cost, while decreasing the dependency on branches (which are limited in their outreach). For banks, financial innovations bring significant cost savings and increase in profitability, which makes them more stable.

The adoption of these FinTech innovations can make banks riskier, as embracing lower-ended customers made possible by FinTech solutions can potentially increase the volatility of bank income and profitability. Financial innovation in the form of mobile money can also heighten operational risk because of increased security and fraud risks in financial institutions. A further complication from a financial stability viewpoint is that the banks have extended their operations through collaborations to encompass non-bank activities with FinTech. This increased linkages between banks and FinTech has given rise to additional potential channels of instability to the banking system.

South Africa's financial system, the most developed in Africa, has experienced a significant growth in FinTech formation and financial innovation in general, which raises an important question about whether financial innovation enhances or impedes the stability of financial systems in South Africa. Despite the growth of FinTech firms and financial innovation in South Africa, the effect of financial innovation on the risk taking behavior of incumbent financial institutions has not been systematically analyzed. In this paper, we examine the effects of financial innovation on financial system stability South Africa.

We first focus on banks, the key players of financial systems and find that FinTech positively affects Z-score of South African banks. FinTech formations are not only associated with lower risk but they also can cause the risk of default to reduce. Our results are consistent with the collaboration hypothesis which posits that faced with intense competition and the development of new technology that can enhance their operations, South African banks collaborate with their more agile entrants and/or have increased their own investment in financial technology. The development of FinTech can benefit incumbent financial institutions through the development of emerging technologies in internet finance, such as third-party payment, P2P lending platforms, reduce the transaction costs of banks, improve the risk management level of banks which ultimately, can improve their performance and lead to a reduction in bankruptcy risk.

However, we find that the relationship between FinTech formation and financial institution bankruptcy risk is non-linear, as the coefficients of FinTech is consistently positive and that of $FinTech^2$ is consistently negative, thus suggesting a U-shaped relationship between FinTech formation and bankruptcy risk. FinTech development initially reduces the insolvency risk of banks and then subsequently intensifies it. That is, as FinTech firms grow, or as banks increase their investment in FinTech development, initial collaboration that leads to decrease in risk gives way to increased competition which affect the stability of bank.

Though FinTech formation reduces bankruptcy risk of banks, the effect is heterogeneous. FinTech negatively affects the bankruptcy risk of large banks, whereas it positively predicts improvements in bankruptcy risk of smaller banks. The results are consistent with the argument that smaller banks, which enjoy a more modern IT infrastructure benefit from Fin-Tech formations (Haddad and Hornuf, 2021). They are also consistent with the conjecture that large banks are slow in adopting and using technological innovations due to a bureaucratic culture compared to small banks, which may adopt innovations proactively (Phan et al, 2020).

Having documented the impact of FinTech formation on default risk of bank, we explore the possible channels through which FinTech development and financial innovation affects bank risk. Given the components of the Z-score, the reduction in risk can emanate from improvements in profitability (ROA), an increase in equity-to total assets ratio (E/TA), or a reduction in the profit variability. A higher ROA and E/A (and higher profit variability) will lead to a reduction (an increase) in bankruptcy risk. We examine the source of the changes in risk and find that FinTech formation strongly and significantly improves the profitability of banks and equity to asset ratio

while it accentuates the profit variability of banks (operational risk). The improvement in profitability and equity position outweigh the increase in operational risk. Thus, the reduction in risk documented for the banks emanates from improvement in profitability and equity to asset ratio. We also examine whether Fin-Tech formations affect the risk of non-bank financial institutions and find consistent results that Fin-Tech formations positively affects the Z-score of non-bank financial institutions in South Africa.

FinTech startups which develop and apply innovative technology to perform tasks previously reserved for banks, such as lending, payments, or investments can substitute for the traditional banks by providing less expensive and more efficient services. On the other hand, the benefits that FinTech presents can lead to more cooperative business models, which can lead to a positive association between financial institution performance and FinTech formations. This cooperation benefits financial institution through the application of innovative technology and better risk management tool which eventually leads to performance improvements. Therefore, we investigate the effects of FinTech startup formations on the performance of overall incumbent financial institutions and find that FinTech formations positively impacts return on assets, stock market returns, and Tobins Q of financial institutions in South Africa. Our results are robust to using aggregate data and different estimation methods, controlling for the effects of the global financial crisis, and to alternative measures of default risk.

Our study contributes to the literature in different ways. First, a growing number of studies examine the effect FinTech and financial innovation on the performance and stability of banks. Phan et al. (2020) investigate a sample of 41 Indonesian banks and find that FinTech negatively predicts bank performance. Haddad and Hornuf (2021) study the effect FinTech startups have on the performance and default risk of traditional financial institutions from 87 countries and document a significantly positive impact of FinTech formations on financial institutions' performance. The empirical literature on the interaction between traditional financial institutions and FinTech start-ups in Africa is still limited, a continent that has experienced significant growth in FinTech sector (Demirgüç-Kunt et al., 2018). To the best of our knowledge, no empirical research has been done that simultaneously and comprehensively examines the impact of FinTech formation on the risk and performance and stability of financial institutions in Africa. The main contribution of our study is to show how FinTech influences financial institutions default risk and performance in South Africa, the most developed financial market in Africa. Our study, therefore,

represents the first empirical study exploring the implication of FinTech development on the stability of financial system. Using both firm-level and aggregate country level data, we show that FinTech reduces default risk and positively influences the performance of both banks and non-bank financial institutions in South Africa except large banks that initial increase in risk.

Second, our study contributes to the literature as it can help reconcile inconsistent findings on the FinTech development on incumbent institutions. Extant literature that examines the relationship between FinTech development and financial institutions report mixed result. Phan et al. (2020) find that FinTech negatively predicts Indonesian banks' performance. Haddad and Hornuf (2021) on the other hand find a positive impact of FinTech on the performance of their sample firms. Our study shows that the FinTech formation-financial institution nexus is non-linear, indicating the initially FinTech formation leads to a reduction in default risk, suggestive of initial collaboration with bank which can turn to increased competition as more FinTech startups enter the market. Thus, our study corroborates that of Wang et al. (2020) who show that there exists a non-linear relationship between Fin-Tech formation and the behaviors of financial institutions over time. Failure to account for this nonlinearity could produce inconsistent results.

Our results have important implications for regulators especially as the FinTech sector grows and becomes more integrated with incumbent financial institution. Though FinTech development generally reduces bankruptcy risk, large banks experience initial higher risk from FinTech development. This increased competition and pressure from FinTech firms could compel incumbent large banks to be more efficient or the increased competition could present a serious stability threat to the South Africa's financial system in light of the high concentration of the banking system with five banks accounting for slightly more than 90% of total bank assets in 2018 (South African Reserve Bank, 2018). However, the non-linear relationship suggests that the increased competition and risk can turn into more collaboration which will lead to a reduction in default risk of large banks. Evidence of collaboration or acquisitions of FinTech firms is increasing. Standard Bank, one of the big-four banks in South Africa bought a Cape Town based FinTech company, Nomanini, which enables the bank to use the FinTech company's platform to

collect data on the informal retail economy and to build up a financial profile on each retailer. Rand Merchant Bank and Nedbank have both partnered with a Cape Town based FinTech start-up, Enterseckt, which provides mobile-security solutions for financial services providers around the world.[1] Such partnerships allow traditional financial institutions to better access FinTech's knowledge. Given the central role of financial institutions in the nation's development, the growth of FinTech firms might to some degree counteract the too systemic-to-fail phenomenon. From a policy standpoint, efforts to promote more collaboration should be encouraged but regulators should still be cautious of systemic risk that can result from data breach.

The rest of the paper is structured as follows. The state of FinTech development in South Africa is presented in section. Background review and hypothesis development appear in Section 3. Data and methodology are discussed on Section 4. We present the results of the impact of FinTech on financial institutions risk and the channels of risk changes in Section 5. The impact of FinTech formation on the performance of financial institutions is presented in Section 6. In section 7, we examine the disruptive effects of the entry of FinTech into financial service on financial systems stability at the country level using aggregate data. Robustness test and policy implications of our results appear in section 8, and Section 9 concludes the study.

2. Context: The State of FinTech In South Africa

South Africa has a fast-growing FinTech industry. As of December 2021, there were over 200 FinTech firms operating in the country, [2] and the number is expected to grow because of the support from innovation hubs and the increasing adoption of technology in financial services. Regulators have also created a conducive environment for FinTech to thrive. For example, the South Africa Reserve Bank has established the Financial Technology Program that assesses the emergence of FinTech and the regulatory implication of FinTech development.

Several FinTech disruptors are imminent in the South African retail banking industry. TymeDigital, the first full service digital bank in South Africa, provides affordable and accessible online banking services. Mobile point of sale (mPOS) players like Yoco and iKhokha are also making inroads in the small and medium enterprises (SME) market, with more than 100 000 small businesses already part of their payment network, while Discovery Bank, with a substantial client

[1] https://ventureburn.com/2019/09/here-are-eight-sa-FinTechs-that-local-banks-are-working-with/
[2] Retrieved from Crunchbase website: https://www.crunchbase.com/

base in its insurance business, has launched a full-service banking platform to serve its clients and is providing the services through digital channels. The platform presents a golden opportunity for the new bank to poach banking clients from established bank especially the 'big four' (Business Tech 2018). Bank Zero which functions solely through an app on smart devices, offers no physical branches, provides credit to its customers and focuses on transactional services with an aggressive low-fees strategy aimed at attracting both retail and business clients. This disruption could affect the margins of incumbent banks which traditionally charge business clients very high fees.

Yemeck (2018) surveys the growth of FinTech in consumer finance applications such as payments and micro credit and finds that growth rates of in sub-Saharan Africa, a region where historically more than 90 percent of the economy has been cash-based, FinTech firms with strong technology-driven offerings have entered the traditional banking environment to 'disrupt' traditional modes of financial technology solutions, provide a myriad of complex offerings ranging from digital payments solutions and information services to simpler savings and deposit-taking products, online banking facilities, securities trading, and financial software (Dapp 2014). Following the pattern in other African countries, the bulk of FinTech solution in South Africa has mainly been in the payment segment with 30% of FinTech solution with 68 active FinTechs (Genesis, 2018). As a result, a large majority of payment FinTechs are third-party payment providers or payment services providers. These disruptors have homed in on consumer pain points and have developed simple solutions which eliminate the friction experienced in traditional financial services processes. They make payments and the money transfer process simpler and less pricey. These FinTech solutions are having a real impact on the lower-end of the market in a commercially sustainable way (Dapp, 2015) and are putting pressure on incumbent retail banks.

The threat to traditional banks emanates from the fact that most of these FinTech firms offer a digital-only presence without any cumbersome and costly branch networks (Popper, 2018), while they threaten to capture the market share held by traditional banks by offering cheaper, more innovative and convenient banking solutions (Weichert, 2017). The ability of FinTech firms to innovatively use technology to find alternative solutions to the needs of banking clients poses a definitive threat to the existence of South African banks in their current form (Coetzee, 2019).

The results from a PwC survey shows that the banking and payments industries are feeling the most pressure from FinTech companies. Two-thirds (67%) of financial services companies ranked pressure on profit margins as the top FinTech-related threat, followed by loss of market

share (59%). One of the ways in which FinTechs exert the margin pressure point through innovation is improvements in operating costs. For instance, the movement to cloud-based platforms not only decreases up-front costs, but also reduces ongoing infrastructure costs (PwC, 2016). South African banks have realized that FinTech firms have the potential to erode and threaten their bank-client relationship (ABSA Bank Ltd, 2016; Nedbank Group Ltd, 2016; Standard Bank Group Ltd, 2016; Firstrand Group Ltd, 2017). The threat to their operating models and the increased competition can negatively affect bank margins, which in turn can result in threats to systemic stability (Arner, et al, 2015; Coetzee, 2019).

2.2. Financial institutions' response to increased competition

To stay relevant, banks have to either face off the competitive threat from FinTech firms or collaborate with them but each response potentially presents increased risk to incumbent banks. The competitive pressure and its attendant effects on margins could induce higher risk taking by incumbent financial institutions. South African banks realize that disruption by non-traditional competitors, especially in the supply chain, is threatening their survival. For example, ABSA regards the disruption of FinTech companies as a key operational risk impacting competitiveness (Barclays Africa Group Ltd 2017). These competitive pressures can affect the margins of banks, and when margins are threatened, franchise value suffers and that in turn induces banks to take higher risk (Mohsni and Otchere, 2014).

On the other hand, there is evidence to suggest that not partnering could lead to the redundancy of banks as we currently know them (Douglas, 2017; Hesse, 2018). However, FinTech partnering with banks raises systemic risks that must be addressed prudently for the sake of financial stability (Deloitte, 2017). Partnership with FinTech firms can increase cyber risk. A big tech firm that provides third-party services to many financial institutions- whether data storage, transmission or analytics - could pose a systemic risk if there is an operational failure or a cyber-attack. Disruptions to these types of third-party services— perhaps due to operational difficulties– are more likely to pose systemic risks the more these third parties are in linking together multiple systemically-important institutions. The susceptibility of financial activity to cyber-attacks is higher the more the systems of different institutions are connected, amongst which there could be a weak link. Thus, greater use of technology and digital solutions expands the range and number of entry points cyber hackers might target.

3. Literature review and Hypothesis development

3.1.Financial innovation and default risk of incumbent financial institutions

Although digital innovation has emerged across the world with its effects on the financial industry well perceived, exactly how this innovation and FinTech growth affect the financial system is not clearly understood (Wang et al., 2021). Extant literature shows that information technology could present great challenges to commercial banks (Holland et al., 1997). The effects can be partly explained by disruptive innovation theory (Christensen, 1997), which posits that new entrants who apply innovative technology to provide more accessible and cost-effective products can create competition in the market. Research shows that FinTech products can either complement or substitute the existing banking and non-banking financial products (Frank, 2009). More traditional institutions, such as banks, that operate on old information technology system are perceived to be slow in adopting new technology (Laven and Bruggink, 2016; Brandl and Hornuf, 2017). Incumbent financial institutions are also subject to restrictions stemming from a regulatory environment that applies to fully regulated institutions (Hannan and McDowell, 1984). Therefore, banks and other financial institutions will likely cede some business activity (Wang et al., 2021), while the new market entrants benefit from a lack of legacy infrastructure and low levels of organizational complexity, which allow them to be more agile, innovate faster, and to be more radical in their approach to innovation (Brandl and Hornuf, 2020). In other words, FinTech startups are likely to absorb the existing business of traditional market players in the financial sector where the latter are operating less efficiently. The extent to which incumbent institutions will be impacted is, however, an empirical issue.

The traditional theoretical banking literature suggests that an increase in competition encourages banks to take excessive risks, which can induce financial instability (Marcus, 1984). In a seminal paper, Keeley (1990) argues that an increase in competition causes the value of bank charters to decline, erodes monopoly rents and encourages bank risk-taking. Hellmann et al (2000) find that increased competition reduces the profitability and franchise value of domestic banks. Consistent with the franchise value effect of increased competition, Jimenez et al. (2010) find a positive relationship between competition and bank risk. An increase in competition can affect a bank's incentive to take high risk; for example, loan officers could lower their credit analysis in an effort to maintain or increase market share, thus resulting in increased non-performing loans (Mohsni and Otchere, 2014).

Several factors could lead to an increase in default risk in the financial industry. Yao et al. (2018) and Kommel et al. (2019) show that the financial products and services the FinTech startups provide are often similar to those of the incumbents. Moreover, banks and other traditional financial institutions are often an integral part of the FinTech business models, which could increase the risk of those who collaborate with them. Studies also suggest that start-ups generally fail more often than established firms (Cressy, 2006). As a result of the interconnections with FinTech start-ups, the risks stemming from FinTech formations could spill over to individual financial institutions (He et al., 2017).

The increase in the involvement of FinTechs in the delivery of financial services in South Africa poses financial stability risks. The risk arises from the reduction in interest-earning income sources for banks as FinTechs and Telcos are leveraging their large customer databases to offer saving and lending services, peer to peer payments services, and money transfer services. This has the potential to undermine the ability of banks to function as monetary policy transmission channel because of their declining importance in domestic credit creation, money supply transmission through holding third party deposits, and the reduced potency of the level of excess reserves banks hold with central banks (Ssenyonga, 2020). In terms of application programming interface (API), the increase in partnership with FinTech and Telcos can cause counterparty risk, technology incompatibility risks and the attendant domino effects on other players in the financial system can potentially increase systemic risks. The attendant interconnectedness of systems of different institutions increases the susceptibility of financial activity to cyberattacks as the range and number of entry points cyber hackers might target increases significantly especially if there is a weak link. Moreover, many banks themselves are actively involved in the development of FinTech technology (Acar and Citak, 2019), which might result in increasing legal and technical risks, such

as data security risk, data privacy risk, and transaction risk, which could increase financial institutions' default risk (Cost of Data Breach Report, 2020). This is consistent with the innovation fragility hypothesis.

Hypothesis Development

From overall financial system stability standpoint, the rise of financial innovation presents potential dangers to financial stability. The innovation-growth school predicts higher bank growth in countries with higher levels of financial innovation, while the innovation-fragility hypothesis posits higher bank fragility in countries with higher levels of financial innovation. If financial innovation and the entry of big tech companies is driven primarily by efficiency gains over incumbent banks, or by access to better information and screening technology, then FinTech makes the financial sector more efficient. This may entice incumbent financial institutions to adopt similar technologies or partner with FinTech firms to exploit the benefits of technology. The financial system could become more diverse, efficient and stable.

FinTech can help financial institutions substantially improve their risk management strategy through big data analytics (Gai et al., 2018). This allows banks to collect and analyze large data sets, including structured and unstructured data and identify market trends, customer preferences, and hidden patterns, thus allowing them to personalize responses, products, and services through a tailored marketing experience. It can also be used to enhance cybersecurity, detect electronic fraud, and prevent potential malicious actions (Gupta & Mandy, 2018). In principle, FinTech products should provide further opportunities for banks by mitigating risks and inform better investment decisions with consistent returns for banks (Chen et al., 2021).

In addition, FinTech involvement in finance could lead to a more diverse and competitive financial system that can have stabilizing effects. They can improve competition and financial inclusion, exert welcome pressure on incumbent financial institutions to innovate, and boost the overall efficiency of financial services. Recent studies show that financial innovation decreases risk. Haddad and Hornuf (2021) analyze the link between FinTech startup formations and the default risk of traditional financial institutions for a large sample of institutions from 87 countries and find that FinTech startup formations decreases stock return volatility and systemic risk exposure of financial institutions.

However, the disruptive nature of financial innovation bodes ill for incumbent financial institutions' stability. As Didenko argues, if big tech entry into banking with innovative products and services is driven primarily by market power, relying on exploiting regulatory loopholes and the effects of network externalities, then this could encourage banks into new forms of risk-taking, given the threats posed by new technology to market incumbents (Didenko 2018). The increased competition and the perceived vulnerabilities of industry incumbents facing disruption from technology-enabled platforms by big tech firms can induce higher risk taking by financial institutions causing higher variability in incumbent firms' profit margins. In addition, the expanded access to financial services by unsophisticated customers and the rapid growth of new platforms as a result of FinTech development can lead to increased risk by incumbents. The foregoing arguments suggest that whether or not financial institutions risk taking incentives increase in an era of heightened FinTech threat is an empirical question.

3.2.Financial innovation and performance of incumbent financial institutions

A number of studies have also examined the implications for banks using FinTech products and how they affect their profitability (Ky et al., 2019; Singh et al., 2016), but the effects of FinTech on banks are also less understood. Prior research shows that information technology is conducive to reducing banks' transaction costs and improving service quality (Lapavitsas and Dos Santos 2008; Shu and Strassmann 2005), although some other studies have claimed that information technology could bring enormous challenges to commercial banks (Holland, et al 1997), while others show that FinTech has no effect on financial institutions performance.

FinTech products and services help banks and other traditional financial institutions gain competitive advantages and boost their market shares by increasing the number of customers and providing additional services (Wang et al, 2021). The digitalization of lending activities can lower transaction costs and improve the efficiency of the loan origination and maintenance processes (BIS, 2017). This could reduce the costs of capital for borrowers and improve the risk-adjusted returns for FinTechs and traditional financial institutions. Moreover, because FinTech startups employ modern technology and use big data, they can at least theoretically better address information asymmetries (Ge et al., 2017; Xu et al., 2018).

Collaboration between FinTech companies would enable financial institutions to capitalize on the innovation advantages held by the FinTech companies (Acar and Citak, 2019). Although most FinTech startups in South Africa are still independent of banks and are open to investment interests, there have been acquisitions of FinTech firms by major banks. Standard Bank, one of the big-four banks in South Africa bought a Cape Town based FinTech company, Nomanini, which enables the bank to use the FinTech company's platform to collect data on the informal retail economy and to build up a financial profile on each retailer, while Rand Merchant Bank and Nedbank have both partnered with a Cape Town based FinTech start-up, Enterseckt, which provides mobile-security solutions for financial services providers around the world[3]. Such partnerships allow traditional financial institutions to better access FinTech's knowledge (Lee and Shin, 2018, Hornuf et al., 2020). Li et al (2017) examine the impact of FinTech on bank stock prices and find a positive correlation between growth of FinTech firms and banks' stock returns.

In contrast, Phan et al. (2020) investigate the association between FinTechs formation and the financial performances of Indonesian banks and find that the FinTech firms negatively affects

[3] https://ventureburn.com/2019/09/here-are-eight-sa-FinTechs-that-local-banks-are-working-with/

the profitability of the banks reduces net interest income-to-total assets (NIM). Others researchers also argue that FinTech has no real effect on banks performance, because FinTech companies typically attract that particular client group(s) which traditional financial institutions do not serve (Haddad and Hornuf (2021), Jagtiani and Lemieux (2018) report in their study find that consumer lending activities on the platform Lending Club have penetrated areas that may be underserved by traditional banks, mostly in highly concentrated markets and areas that have had fewer bank branches. For example, risky startup firms and consumers that lack a credit history often do not obtain access to bank credit, especially if the desired loan amounts are small and are associated with high transaction costs (Demos, 2016; Hayashi, 2016) but the FinTechs fill this gap. The foregoing discussion shows that the impact of FinTech formation in financial institutions' performance is an empirical issue.

4. Data and Methodology

4.1. Data and measures

The study covers the period 1998-2020. This period coincides with an era when South Africa experienced a significant growth in FinTech firms (see figure 1). The growth of FinTech firms makes South Africa an interesting case to analyze how FinTech influences bank default risk and performance in Africa. It is customary to use patent and R&D data as proxy of financial innovation. However, patent or R&D expenditures are typically not collected for financial institutions. The lack of data has impeded rigorous analysis of financial innovation across countries (Frame and White (2004)). The problem is more acute in developing countries where sophisticated financial products don't exist or are not fully developed. However, data on R&D expenditures in the financial intermediation industry for South Africa is available from the Analytical Business Enterprise Research and Development database (ANBERD), the only African country covered in

the database, but the data is too sparse to undertake any meaningful analysis using *Financial R&D* as a measure of financial innovation. To examine the impact of financial innovation on financial system stability in South African we use the number of FinTech firms as a proxy for financial innovation. Bernstein et al., 2017, Phan et al (2020) and Haddad and Hornuf (2021) also use this variable as a proxy for financial innovation to examine the effect of FinTech on bank performance and financial institutions default risk. Overall, we identified 147 FinTech startups over our study period. As figure 1 shows, the last decade has witnessed a strong growth in financial technology firms in South Africa and since these FinTech firms have the opportunity to take over several key functions of traditional banks (Li et al., 2017) and replace the activities currently undertaken by bank. Thus, they can trigger a substitution effect (Phan et al., 2020) with the attendant stability implications for the financial system stability.

The activities of FinTech firms might affect not only the business models of banks but also those of other financial institutions; hence, we assess the impact of FinTech formation on the default risk and performance of banks and non-bank financial institutions as well. The data on FinTech firms are obtained from CrunchBase database. The database does not provide granular information on the type of FinTech firms but Genesis Analytics (2019) shows that the bulk of the FinTech activities are centered on *payment* (30%), followed by B2B Tech Support (20%) and Lending (12%), investment (10%), Insurtech (9%), Financial planning advisory (7%), savings and deposits (6%), etc. Firm specific data was obtained from financial statements and stock returns were obtained from Bloomberg and CompuStat World DatabaseData availability limited our sample size to 70 banks and non-bank financial institutions. Appendix A contains the list of variables used in the study and their definitions.

To test our main hypothesis, we use accounting and market measures of risk in our analysis. We follow Demirgüç-Kunt and Maksimovic (2002), and Deniz et al (2012), Laeven and Levine (2009), and Houston et al. (2010) and use the Z-score as a measure of default risk of financial institutions. The Z-score, which is widely used as a measure of bank distance to default (Laeven and Levine (2009) and is recognized by the World Bank as a measure of the stability of the banking system (Sysoyeva, 2020) is expressed as follows:

$$Z{-}score{=}(ROA){+}(E/TA))/\sigma ROA \quad (1)$$

where ROA represents the return on assets of financial institution, E/TA is equity-to total assets ratio, and σROA is the standard deviation of ROA. The Z-score combines profitability, leverage and return volatility in a single measure and it measures the number of standard deviations that returns have to fall in order to diminish equity. The score increases as profitability and capitalization levels improve and falls with an increase in the variability of ROA. A higher Z-score implies a lower default risk and greater stability of the financial institution.

We also consider the volatility of stock returns as a measure of financial institution default risk. This measure, which has been widely used in prior research (including Haddad and Hornuf, 2021), and Sun and Liu (2014), captures the market's perception of the risk inherent in banks' assets, liabilities, and off-balance sheet positions (Pathan, 2009). For robustness tests, we follow prior studies and consider standard deviation of the return on assets (Laeven and Levine, 2009; Lepetit et al., 2008) and the ratio of non-performing loans-to-total loans (Jiménez et al., 2013) as measures of risk. To test our hypothesis relating to performance, we calculate the net interest margin, return on assets, and Tobin's Q as measures of financial institutions performance. Tobin's Q traditionally measures the sum of the market value of equity and the book value of liabilities

divided by the book value of assets. Following Anilowski et al. (2007), we use annual stock returns as our market-based measure of performance.

4.2. Methodology

To establish the relationship between FinTech formation and financial stability, we follow Phan et al (2020) and Haddad and Hornuf (2021) and estimate a panel model of the general form expressed as:

$$Risk_{i,t} = \alpha_i + \beta_1 LnFinTecht + \beta_2 Risk_{i,t-1} + \sum_{n=4}^{M} \beta n CONTROLS + \varepsilon_{i,t} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where Risk is one of the measures of stability for firm i at time t. In the performance regressions, we replace Risk with PER, where the variable represents one of three dependent variables: return on assets (ROA), annual stock returns, and Tobin's Q. $FinTech_t$ is the FinTech measure at time t. To deal with the skewness in the distribution of this variable, we use the natural logarithm of number of FinTech companies. A negative sign on the coefficient of FinTech implies that the presence of FinTech firms bodes ill for the incumbents financial institutions, and hence the stability of the financial system. On the other hand, a positive coefficient will imply that FinTech firms make financial institutions more stable, ε_{it} is the error term representing omitted variables that determine Z-score.

To account for financial institution and cross-country heterogeneity, we include several variables, which are frequently used as controls in the bank risk and performance literature. Following Pathan and Faff (2013) and Berger et al. (2017), we control for firm size, capital ratio, leverage, the cost income ratio, the interest income share, and net income growth rate. Firm Size is proxied by Total assets and it is expected to have a negative impact on the Z-score given that the larger the bank, the more likely that it is subject to too big-to-fail tendencies. Also, large firms are not agile enough to respond quickly to the threat from FinTech firms; therefore, FinTech formation is expected to have a negative effect on their performance and stability. On the other hand, large banks can earn higher profit by lowering deposit rates and maintaining higher lending rate in a non-competitive environment (Flamini et al, 2009). Income growth rate accounts for differences in risk preferences across banks and the variable is expected to have a negative effect on the Z-score, our key risk measure. Capital ratio is included because extant literature shows that

higher capital is a positive signal of a bank's prospect that it may not require external funding (Berger, 1995) and is more profitable. Thus, the variable can impact positively on the firms and hence less risky. Interest income share is used as a control variable because it can negatively impact banks' profitability if the share of interest income relative to total income is high (Dietrich and Wanzenreid, 2014) since in general, banks obtain higher margins from asset management activities (Phan, et al. 2020).

The dynamic specification of equation (1) allows us to account for the fact that the stability of the financial sector (our dependent variables) might be time-persistent phenomenon. However, the presence among the right-hand side variables of Z-score$_{t-1}$, which is correlated with the error term, will lead to inconsistent parameter estimates when firm heterogeneity is accounted for by means of conventional fixed- or random-effects estimators (Baltagi 2001). Moreover, equation (2) can be affected by the presence of other endogenous regressors and reverse causality issues. In particular, the state of the financial sector might have a positive or negative effect on profitability of financial institutions which in turn can affect their risk taking and the stability of the financial system. To deal with these issues, we follow prior research (e.g., Shaban and James, 2018, Phan et al., 2020) and employ the Generalized Method of Moments (GMM) estimation techniques. Specifically, we use a two-step GMM system dynamic panel estimator (Arellano and Bover, 1995) to estimate the model. This approach allows us to treat the explanatory variables as endogenous using their past values as instruments (Wintoki et al., 2012).[4] It is important to determine the correct number of lags to sufficiently capture the past. Older lags are more likely to be exogenous with respect to the residuals of the present and should therefore be valid instruments (Haddad and

[4] Although the first-difference GMM controls for possible measurement errors and endogeneity bias, as pointed out by Blundell and Bond (1998), the lagged levels of the explanatory variables are weak instruments for the variables in differences when explanatory variables are persistent. The system GMM estimator (Arellano and Olympia Bover 1995; Blundell and Bond 1998) allows us to address these shortcomings by fully exploiting the cross-firm variation in the data. In the system GMM approach, specifications in first-differences and in levels are combined. Based on mild stationarity restrictions on the initial condition processes, the system estimator augments the difference GMM by including an equation in levels and by estimating simultaneously in differences and levels, with the two equations distinctly instrumented (Sysoyeva, 2020).

Hornuf, 2021). We follow Wintoki et al. (2012) and Haddad and Hornuf (2021) and include two lags to capture the persistence of performance of financial institutions. The validity of the instruments used can be evaluated using the Sargan test of over-identifying restrictions.

5. Results

5.1: Summary statistics

Table 1 presents the summary statistics of our dependent, explanatory, and control variables. The Z-score, our measure of insolvency risk has a mean value of 29.3 and a standard deviation of 59.8 indicting that the sample of 242 firms contains both stable and unstable financial institutions. The profitability of the sample, as measured by ROA, averaged 2.87% although there is a wide variation in performance. The net revenue growth averaged 5% during the study period. Credit risk, as proxied by NPL shows a mean non-performing ratio of 2.96%, which appears to be a good performance relating to the management of their loan portfolios. The correlation matrix is reported in Panel B. Four indicators of financial risk are employed, namely, insolvency risk (Z-score), credit risk (NPL), operational risk (standard deviation of ROA) and stock market risk (stock return volatility). The Z-score is positive and significantly correlated with FinTech. This suggests that FinTech growth is associated with lower insolvency risk. Credit risk is negatively correlated with profit efficiency, suggesting that interest revenue declines when non-performing loans increase.

5.2. Benchmark model results

5.2.1. The effect of FinTech formation on bank risk taking

We report the results of our baseline regression in Table 2. Because the Z-score is often highly skewed (Laeven and Levine, 2009), we also use the natural logarithm of the Z-score in our estimations as well. The results are presented for each of the 2 variants of the Z-score as the dependent variables. For each model, the first regression is estimated using only the FinTech

variable, we then introduce firms specific controls that have been shown to impact the bank and non-bank risk taking behavior.

In Panel A, we examine how FinTech formation affects the risk of banks. Using the Z-score as the dependent variable, we find that FinTech start-up formations in South Africa positively affects Z-score. The coefficient remains positive and significant when we introduce the control variables. In the full regression, (model II), the coefficient of 13.37 is significant at 5%, implying that a 1% change in the number of FinTech firms is associated with a 13.37% decrease in the Z-score of the banks. Using the Ln Z-score as the dependent variable, we observe that the coefficient of FinTech changes signs when we introduce the control variables. The begs the question whether the relationship is linear.

5.2.2. Is the relationship between FinTech formation and bank risk taking non-linear?

It is conceivable that the relationship between FinTech formation and bank risk taking is non-linear. Initial competition between FinTech firms and incumbent financial institutions will give way to collaboration. Alternatively, initial collaboration which leads to a reduction in risk can give way to increased competition and increased risk as the number of FinTech firms increases. To explore this conjecture, we introduce $FinTech^2$ as another independent variable and re-estimate our baseline regression and present the results in Panel B. The results provide evidence of a non-linear relationship between FinTech development and banks risk because the coefficients of *FinTech* is now consistently positive and that of $FinTech^2$ is consistently negative and mostly significant in all the regressions using both Z and Ln Z-score as the measure of risk. Interestingly, the results based on Z-score and Ln Z-score are similar and consistently positive with and without the control variables, although the size of the coefficient of FinTech is smaller in the Ln Z-Score

regression. The positive coefficient of *FinTech* and the negative coefficient on $FinTech^2$ implies that the nexus between FinTech and bank risk taking is U-shaped. FinTech development initially reduces the insolvency risk of banks and then intensifies as the number of FinTech firms increases. The probability values of the Sargan tests of over-identifying restrictions imply that the null hypothesis of valid instruments cannot be rejected.

Our results are consistent with the collaboration hypothesis. Faced with intense competition and the development of new technology that can enhance their operations, South African banks have to either compete fiercely with FinTech firms or collaborate with their agile entrants. Banks, including Standard Banks, Rank Merchant Bank and Nedbank have either strengthened their strategic cooperation with technology giants and/or have increased their own investment in financial technology. The development of FinTech benefits incumbent financial institutions through the development of emerging technologies in internet finance, such as third-party payment, P2P lending platforms, reduce the transaction costs of banks, improve the risk management level of banks. All these lead to a reduction in bankruptcy risk (increase in Z-sore) and increase the stability of the banking system. This positive effect of FinTech on banks is consistent with the findings of Pierri and Timmer (2020) and Haddad and Hornuf (2021). The non-linear relationship implies that as FinTech firms grow in numbers, or as banks increase their investment in FinTech development, competition increases which can affect the stability of bank. This finding is consistent with that of Shen and Pin (2015) and Deng et al (2021) who find that the impact of the development of Internet finance on banks' risk-taking exhibits a 'U'-shaped trend, as the bankruptcy risk first decreases and then increases with increases in the number of FinTech firms.

--- Insert Table 2 Here ---

5.3 Lag effect of FinTech startup formations on bank risk

The results presented in Table 2 indicate that FinTech formation is associated with a reduction in bankruptcy risk. However, these results are suggestive of a contemporaneous relationship between bank solvency risk and FinTech formation. Given that FinTech formation occurs evenly throughout the year, and also that newly formed FinTech firms may not impact incumbents firms' operations contemporaneously in the year of their formation, it is reasonable to expect that the impact of FinTech formation on banks risk will occur with a lag. In this section, we test whether FinTech predicts bank risk by re-estimating our baseline model using the lag of FinTech as our main independent variable and present the predictive model results in Table 3.

The result shows that the number of FinTech startup formations positively predicts incumbent banks' risk. The coefficient of the lag of FinTech is consistently and significantly positive in all the regressions using both measures of Z-score. FinTech positively and statistically significantly influences default risk (2.55, t-stat.=2.66 in the Ln Z-score regression). Our results are consistent with those of Haddad and Hanuf (2021) who find that financial institutions exposure to systemic risk decrease with more FinTech startups entering the market. The results in Table 2 and 3 imply that FinTech formations are not only associated with a lower risk but also they cause the risk of default of South African banks to reduce. As expected, larger banks generally exhibit higher default risk (lower Z-score). The coefficient of Ln Asset is negative and significant and Leverage accentuates the default risk of bank.

--Insert Table 3 About Here ---

5.4: Channels of risk reduction: Profitability (ROA), capital adequacy ratio (CAR), and/or asset return volatility (σ_{ROA})

Our results indicate that incumbent banks experience a reduction in risk as a result of FinTech development. Given the components of Z-score, the reduction in risk can emanate from improvements in profitability (ROA), an increase in equity-to-total assets ratio (E/TA), or a reduction in profit variability. A higher ROA and E/A (higher profit variability) will lead to a reduction (an increase) in bankruptcy risk. Extant literature shows that information technology is conducive to reducing banks' transaction costs and improving service quality (Martín-Oliver and Salas-Fumás 2008; Shu and Strassmann 2005). The improvement in profitability can enhance the equity-to total assets ratio and reduce earnings variability **(** $\sigma_{\mathrm{R}OA}$**)**. On the other hand, increased competition and the perceived vulnerabilities of industry incumbents facing disruption from technology-enabled platforms by big tech firms can induce higher risk taking by banks causing higher variability in bank's profit margins **(** $\sigma_{\mathrm{R}OA}$**)**.

We examine the sources of the changes in risk by re-estimating equation 2 using ROA, E/TA, and volatility of ROA as dependent variables and present the results in Table 4. We find that FinTech formations is positively related to all the three components. FinTech formation strongly and significantly improves the profitability of banks which also reflects in equity to asset ratio. The coefficient of FinTech in the full ROA model of 13.71 is strongly significant at 1% (t-statistic = 6.46). However, FinTech accentuates the profit variability of banks. The improvement in profitability and equity position outweigh the increase in operational risk. Thus, the reduction in risk documented for the banks emanates from improvement in profitability and equity to asset ratio. The results are consistent with the findings of prior studies including Haddad and Hornuf (2021) that document significantly positive effects of FinTech formations on the profitability of financial institutions.

--- Insert Table 4 About Here ---

5.5. Is the effect of FinTech formation on bank risk dependent on size of incumbents?

Next, we test whether the effect of Fin-Tech start-up formations in South Africa differs with respect to large and small banks. Recent research (e.g., Talavera et al. 2018 and Phan et al, 2020) suggests that characteristics of financial institutions such as size are important predictors of performance. Large universal institutions might benefit from alliances with FinTechs, which help them to obtain specialized knowledge and improve their performance through product related corporations or partial acquisitions of FinTechs (Hornuf et al. 2020) and hence can reduce their risk more than that of small banks. On the other hand, large financial institutions often have the financial wherewithal to forcefully pursue change through acquisitions and in-house experimentation and compete with FinTech firms. On the other hand, smaller banks are more agile and can adapt quickly to changes and might benefit from alliances with FinTech collaboration. Moreover, smaller, more specialized financial institutions might already possess a more modern IT infrastructure and hence could benefit more from FinTech formations. We, therefore, expect that FinTech will impacts large and small banks differently. Using total assets of a bank as a proxy for size, we split the sample into large and small banks and estimate our main regression separately for large and small banks separately to ascertain whether the development of FinTech startups has a differential impact on financial institutions' risk. To ascertain whether this potential heterogeneity could account for the non-linearity that we observed earlier, we include $FinTech^2$ in both regressions.

The results, presented in Table 5 are noteworthy and shows that FinTech formation has heterogeneous effects on large and small banks. Panel A which shows the contemporaneous and predictive effects of Fin-Tech formations on bankruptcy risk of large banks indicates that there is a negative and significant association between Fin-Tech start-ups formations and the bankruptcy

risk of large financial institutions in both the Z-score and Ln Z-score regressions, suggesting that FinTech firms make large banks more unstable. The lag regression results presented in columns 3 and 4 show that FinTech formation can predict bankruptcy risk of large banks in South Africa. Large banks bankruptcy risk is negatively affected by FinTech, with a slope of −5 (t-statistics = −2.61), and −9.63 (t-statistics = −2.14) in the contemporaneous and lag effect regressions, respectively. However, the results presented in Panel B show that FinTech formations positively predicts improvement in bankruptcy risk of smaller banks.

Another striking result is that the non-linear relationship appears to be more related to large firms. The coefficient of $FinTech^2$ is significant in all the 4 regressions (association and prediction regressions) for large bank, whereas the nonlinearity is weak for small banks. In fact, for smaller banks, we do not observe any significant nonlinear relationship between FinTech formations and bankruptcy risk of small banks in both the contemporaneous and lag effect regression models when we use Ln Z-score as the measure of risk.

Overall, we document negative effect of FinTech on large banks bankruptcy risk but positive effects on small banks. These results are consistent with the argument that smaller banks, which are a more specialized kind of financial institutions, enjoy a more modern IT infrastructure and they benefit from Fin-Tech formations (Haddad and Hornuf, 2021). They are also consistent with the conjecture that large banks are likely to be slow in adopting and using technological innovations due to a bureaucratic culture compared to small banks which may adopt innovations proactively Phan et al (2020). The literature suggests that larger firms may respond slowly technological transformations due to legacy systems that demand substantial modification, and therefore must bear substantially more costs in reorganizing compared to smaller firms that are more apt at adjusting to internal and external changes related to their operations (Scott et al, 2017)).

--- Insert Table 5 About Here ---

5.6. FinTech and default risk of non-bank financial Institutions and the financial sector

The focus of the analysis thus far has been on banks, the key players in the financial system. In this section, we examine whether Fin-Tech formations affect the risk of non-bank financial institutions (e.g., insurance companies and wealth management funds). We use the same measures of default risk, i.e., Z-score and the same controls except that we substitute banks' interest income for cost-to-income ratio since the former is not common in non-bank financial institutions. The results are presented in Table 6. Panel A shows the contemporaneous and lag effects of Fin-Tech formations on non-bank financial institutions' default risk and Panel B presents similar effects on the whole financial sector.

Consistent with the results presented in Table 3 for banks, FinTech formations positively affects the Z-score of non-bank financial institutions. The coefficients for FinTech formation imply that a 1% change in the number of FinTech firms is associated with a 3.69% decrease in the default risk of non-bank financial institutions. The results also indicate that FinTech predicts a lower default risk of non-banks financial institutions in South Africa. We present the contemporaneous and the lag effects of FinTech formations on the default risk of the full sample in Panel B and find similar results. FinTech firms make the financial system of South Africa more stable.[5] The magnitude of the effects on non-bank financial institutions is smaller than that of banks reported in Table 3.

--- Insert Table 6 About Here ---

6.0. Effects of FinTech on performance of banks and non-bank financial institutions

[5] The results based on Ln Z-score are similar and therefore have not been reported for the sake of brevity.

The impact of FinTech formation on the performance of financial institution is not clear. On one hand FinTech startups, which develop and apply innovative technology to perform tasks previously reserved for banks such as lending, payments, or investments, can substitute the traditional banks by providing less expensive and more efficient services (Phan et al, 2020). This suggests that FinTech growth will negatively influence bank performance. On the other hand, the benefits that FinTech presents can lead to more cooperative business models which can benefit financial institutions. Previous research (e.g., Vives, 2019) posits that financial institutions rethink and reshape their business model when confronted with competitive pressure and one potential way they accomplish performance improvements is to cooperate with and integrate the new players into their organization (Hornuf et al. 2020). This cooperation benefits financial institution through the application of innovative technology and better risk management tool which eventually leads to performance improvements.

In this section, we investigate the effects of FinTech startup formations on the performance of incumbent financial institutions and present the results in Table 7. The columns represent the three dependent variables measuring performance, namely return on assets, stock returns and Tobin's Q. In these regressions, we use the lag of FinTech as the independent variable. The results indicate that FinTech formation is a significant predictor of financial institution performance. In all the three models, FinTech formations positively predicts return on assets, stock returns and Tobins Q of financial institutions in South Africa.

In terms of economic significance, the coefficients imply that a 1% increase in FinTech firms entering the market in a given year increases financial institutions return on assets by 8.96%, annual stock returns by 15.26% and Tobin's Q by 0.85% on average during the following year (the mean values of ROA, stock returns and Tobin's Q as 2.874%, 26.87% and 4.82%, respectively, as

shown in Table 1). The magnitude of the effect is similar to that of Phan et al. (2020) who find that for Indonesia, return on assets change by 9.32 for every extra FinTech startups entering the market. Another closely related study is that of Haddad and Hornuf, (2021) who find for a sample of financial institutions from 87 countries that an extra FinTech firm entering the market in a given year increases financial institutions return on assets by 3.46% and annual stock returns by 7.89% of the mean value respectively, the next year.

--Insert Table 7 About Here ---

7. FinTech and financial institutions stability: Country-level analysis

The analysis thus far is based on firm level data. Firm level data is useful in demonstrating firm heterogeneity within a sector and country. Since the focus is on South Africa, the results may be difficult to generalize to other countries because of differences in the reporting system underlying data and/or the methodology used to compile the data. For generalization purposes, there is a need to use data that has been compiled using the same methodology for different countries. We obtain country level data on bankruptcy risk and other related variables from Global Financial Development Database (GFDD) that allows us to estimate the effect of FinTech on financial stability using aggregate data. The GFDD database is an extensive dataset of financial system characteristics for 214 countries. It contains annual data on the stability of financial systems, specifically aggregate (country-level) Z-score, non-performing loans, bank interest margin, cost to income ratio, among others etc. The database draws upon a common analytical framework as well as definition of common methodologies when compiling data. This allows for better cross-country

comparison of the data and generalization of the results. Using this aggregate data, we estimate our main regression and report the results in Table 8.[6]

Panel A of Table 8 shows the contemporaneous effects of FinTech start-ups. FinTech formation positively affects bank Z-score. The coefficients imply that for a 1% change in the number of FinTech firms in South Africa is associated with a 3.26% decrease in the country's level risk. Similar and consistent results are obtained when ln Z-score is used as a measure of bankruptcy risk. In columns 5 and 6, we report the results using the lag of FinTech start-up formations for the country-level default risk regression. We find that the lag of FinTech start-up formations in South Africa is positively and significantly related to the country's aggregate bank Z-score, suggesting that, on average, the lag of Fin-Tech start-ups can decrease the financial institutions' default risk. These results are consistent with the firm-level results documented in Table 3.

--- Insert Table 8 About Here ---

8. Robustness Test

8.1. Controlling for the effects of the Global Financial Crisis (GFC)

To test the robustness of our results, we carry out four additional tests. First, in the analysis thus far, we do not control for the effects of financial crisis. Our results could be confounded by the effect of the financial crisis. In this section, we re-estimate our main regression while controlling for the effect of the financial crisis by including a GFC dummy defined as 1 for 2008-2009 and 0 otherwise. The results augmented model presented in Table 9 are similar to our previous findings, i.e., FinTech formation significantly reduces and predicts the default risk of banks and other financial institutions in South Africa. With regard to performance, we find that FinTech start-up

[6] The squared term is excluded from the regression since its inclusion reduces both R-squared and adjusted R-squared.

formations continues to positively affect financial institutions performance, as shown by the increase in ROA, stock return and Tobin's Q even after controlling for the effect of the global financial crisis.

We also examine whether the bankruptcy risk and performance of financial institutions has changed in the aftermath of the global financial crisis. To ascertain this, we introduce Post-GFC dummy that takes a value of 1 for the period after the 2007-08 and 0 otherwise and present the results in Panel B. The coefficient of the dummy is significantly positive in the risk regressions, suggesting that the risk of financial institutions have reduced in the period after the global financial crisis. The profitability and value (Tobin's Q) has improved but the returns are significantly lower in the post crisis period.

--- Insert Table 9 About Here ---

8.2. Alternative measure of Z-score

Our main measure of bankruptcy risk, the Z-score consists of three components: (i) return on assets (ROA), equity-to-assets ratio, and standard deviation of ROA. In estimating the measure, we use a 3-year moving average to estimate the volatility of ROA. The rolling moving average method involves dropping the first variable, which may affect the estimated measure. Moreno et al. (2021) estimate and compare the explanatory power of six different measures of Z-score and find that the best Z-score measure that incorporates the most statistically significant variables in the risk model is the one uses the standard deviation of ROA calculated over the full period. The advantage of this Z-scores is that it enables the construction of time-varying Z-scores that do not require initial observations to be dropped (Lepetit and Strobel, 2013, Moreno et al, 2021).

To ascertain whether our results are not dependent on how we estimate our key risk measure, we employ the Z-score proposed by Moreno et al, (2021) that uses the standard deviation

of ROA calculated over the full period. Beck and Laeven (2006) also use this type of Z-score in their study. The results of this alternative measure of Z-score is presented in Table 10, columns 2 and 3. Consistent with the main findings, the coefficient of FinTech is positive and significant, signifying a reduction in bankruptcy risk, thus confirming our earlier results that FinTech formation predicts financial institution stability. The other explanatory variables remain qualitatively the same.

8.3. Alternative measure of bank risk: Non-performing loans (NPL)

To provide further robustness check, we re-estimate our baseline equation using the ratio of non-performing loans-to-gross loans as an alternative accounting-based measures of risk as the dependent variables. Beck, Demirgüç-Kunt, and Levine (2019) show that the NPL can impact the probability of a systemic crisis in the banking sector when distressed assets exceed 10% of total bank assets. Our regression results are presented in Table 10 (columns 4 and 5). Consistent with our previous findings based on Z-score, both the contemporaneous and lag effects show that *FinTech* is associated with a reduction in non-performing loans of banks. The rest of the results are also consistent with our previous findings based on default risk.

--- Insert Table 10 About Here ---

8.4. Use of Market-based measure of risk: Stock return volatility

Our key measure of risk, Z-score is largely based on accounting data, which is historical in nature and may not accurately reflect the actual conditions of a financial institution. Moreover, if financial institutions are able to smooth out the reported data, the Z-score will provide an overly positive assessment of the financial institution's insolvency risk ((Laeven and Majnoni, 2003, Haddad and Hornuf, 2021). Also, extant literature shows that changes in risk could be driven by changes in market expectations regarding future profitability, return, or growth opportunities (Mohsni and

Otchere, 2014). Therefore, to obtain further insights into the influence of FinTech development on financial institutions' risk, we use market-based proxies of risk, namely stock return volatility as our measure of risk in our baseline regression and report the results in columns 5-10 of Table 10. The results show that the coefficient of FinTech is consistently negative, implying a reduction in stock return volatility for banks, non-bank financial institutions and the full sample. In summary, our results are robust to using different measures of risk, different data types, different estimation method, and to controlling for the effect of the global financial crisis.

8.5. Policy Implications

The potential disruptive effects of FinTech rise to a level where they present very real systemic threat to the stability of the financial system. The regulatory concerns are more acute for South Africa given the highly concentrated nature of the industry, with five banks accounting for slightly more than 90% of total bank assets (South African Reserve Bank, 2018). In fact, the Intergovernmental FinTech Working Group (IFWG), which includes representatives from regulatory authorities such as the Financial Intelligence Centre, the Financial Sector Conduct Authority, the South African Reserve Bank (SARB) and National Treasury, acknowledges that with the increase in FinTech firms, the regulatory environment has changed substantially (Intergovernmental FinTech Working Group, 2018). Consequently, SARB has established a FinTech Unit to monitor the financial, operating and systemic risks posed by FinTech (SARB 2017).

Our findings that FinTech development is generally associated with a lower probability of default of financial institutions is an important contribution to the discourse and can inform policy making by the SARB especially as the FinTech sector becomes more and more integrated with incumbent financial institutions. The reduction in bankruptcy risks nonetheless, it is important for

regulators to monitor the players closely, in particular given the finding of a heterogeneous effect on small and large firms, as large banks experience initial increase in risk with the growth of FinTech. Given the inverted U-shaped relationship between FinTech development and large banks' default risk, the initial threat that FinTech formations pose to large banks gives way to collaboration between FinTech and large banks or banks themselves invest in FinTech and therefore, the higher risk initially experienced by large bank reduces as the FinTech sector grows.

South African bank including Nedbank are partnering with FinTechs. While this bodes well for the banks, the collaboration raises systemic risks that must be addressed prudently for the sake of financial stability as it can increase cyber risk. A big tech firm that provides third-party services to many financial institutions (whether data storage, transmission or analytics) could pose a systemic risk if there is an operational failure or a cyber-attack. Disruptions to these types of third-party services— perhaps due to operational difficulties—are more likely to pose systemic risks the more these third parties are linked together with multiple systemically important financial institutions. The susceptibility of financial activity to cyber-attacks is likely to be higher the more the systems of different institutions are connected (Deloitte, 2017).

Furthermore, banks and other traditional financial institutions are often an integral part of the FinTech business models, which could increase the risk of those who collaborate with them. Finally, extant research also suggest that startups generally fail more often than established firms (Cressy, 2006). Banks and other traditional financial institutions that collaborate with FinTech firms become an integral part of the FinTech business models. As a result of the interconnections between FinTech and financial institutions, the risks stemming from FinTech formations failure could spill over to individual financial institutions. This potential systemic risk must be addressed prudentially.

9. Summary and conclusion

We examine the effect of FinTech startup formations on the stability and performance of financial institutions in South Africa - a country that has experienced a remarkable growth in FinTech between 2010 and 2020. We find robust evidence that FinTech startup formations have a positive and statistically significant effect on the stability of financial institutions stability. They contribute to reduce the financial institutions' default risk. FinTech development also leads to improvement in operating performance of financial institutions. Our results are consistent with those of previous research which assert that banks and other financial institutions could see performance improvements by partnering with FinTechs and integrating them in their organization (Hornuf et al. 2020). Overall, our findings are consistent with previous research that argue that technological improvements and new business models improve the efficiency of risk management and consequently reduce default risk.

Further investigation confirms the existence of a non-linear (i.e., U-shaped) relationship between FinTechs and the risk of financial institutions. In other words, although initially the default risk of traditional players in the financial sector decreases, but the risk begins to increase as FinTech formations further develops. They also corroborate the finding that risk taking begins to decrease as FinTech further develops (Wang et al, 2021). However, for banks, the effect of FinTech formation is heterogeneous, as large banks experience an increase in default risk whereas small banks' exposure to systemic risk with the development of FinTech startups.

Our study has important implications for mangers and regulators. First, from financial institutions' perspective, a collaboration strategy, in which banks and other financial institutions partner with FinTech to provide a range of technological capabilities would be beneficial for incumbent financial institutions. Second, the evidence that smaller banks are positively affected

by FinTech startups, presumably because of their ability to respond quickly to .implies that large banks could simplify their operational processes in way that will enable them to quickly respond to any changes in the business environment. The finding that FinTech formation is negatively associated with large bank risk calls for caution on the part of policymakers as it can accentuate the too-big-to fail problem, while collaboration between banks and FinTechs can create stability problems because the risks stemming from failure of FinTech firms or data breaches could affect the whole financial system because of the interconnectedness that results from such partnerships.

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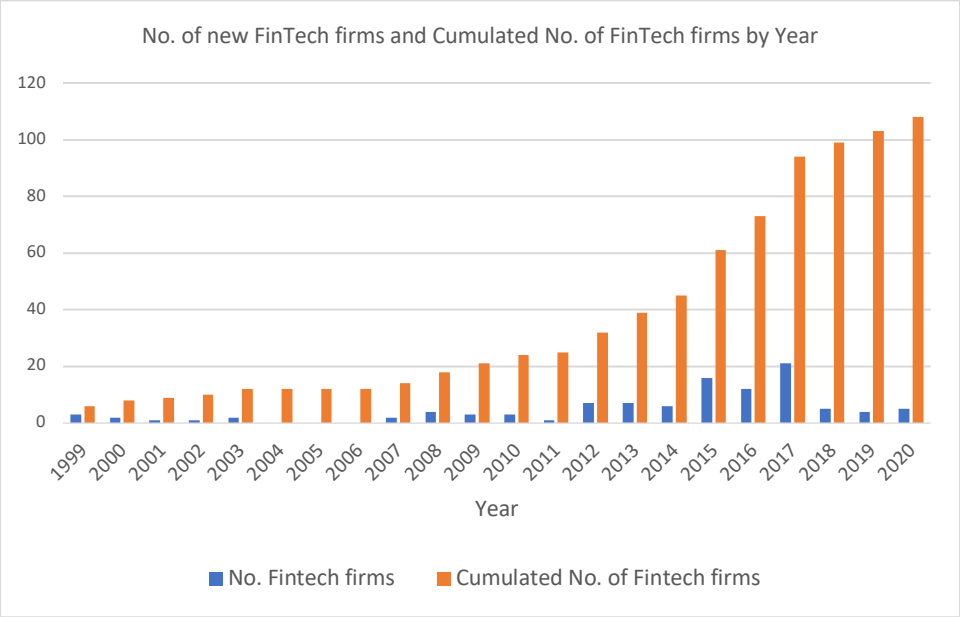
Figure 1: FinTech firms in South Africa (1999-2020)



This figure plots the number and accumulated number of FinTech firms established in each year from 1999–2020. Data are obtained from the ….

Table 1. Summary Statistics and Correlation matrix

This table presents selected descriptive statistics for the variables in our regressions. The statistics include the mean, median, standard deviation (SD), 25% percentile, 75% percentile, skewness, and kurtosis. Panel A reports the descriptive statistics and Panel B shows the correlation matrix.
Panel A: Descriptive Statistics

Variable	Mean	Median	Standard Deviation	1st Quartile	75%	Skewness	Kurtosis
Equity	45430.674	1149.000	509865.873	214.300	8973.000	15.446	213.676
Size	466868.050	4969.400	5105357.820	805.300	59374.200	15.484	215.554
ROE	12.415	15.815	36.386	7.098	24.260	-2.766	23.861
Capital Ratio	25.233	19.640	49.306	7.930	41.120	-9.299	120.443
ROA	2.874	2.100	32.154	0.680	7.330	11.220	289.767
SD ROA	8.465	1.645	33.199	0.411	5.797	10.476	110.473
Z-score	29.340	13.212	59.833	4.459	32.540	9.073	115.634
Cost to Income	1.174	1.624	17.076	0.553	3.011	-20.596	492.900
Interest Income Share	0.672	0.071	2.829	0.028	0.576	0.273	49.826
Price to Book	2.171	1.652	3.637	1.069	2.626	5.686	87.031
Net Income Growth	0.049	0.083	6.627	-0.427	0.409	-2.138	112.423
Volatility	56.905	36.270	63.291	27.320	55.110	3.553	16.145
Q	4.818	1.090	28.551	1.010	1.430	10.419	107.235
Stock Price Return	26.874	6.061	185.808	-13.132	28.130	12.157	127.483
Debt to Equity	295.277	144.875	354.744	56.860	341.180	1.659	1.761
NPL Ratio	2.958	2.330	4.211	0.016	4.138	4.578	30.416

Panel B: Correlation Matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1.ROA	1.00																
2. ROE	0.70	1.00															
3. SD ROA	-0.03	-0.32	1.00														
4. Z Score	0.03	0.10	-0.49	1.00													
5. Ln Z Score	0.12	0.23	-0.78	0.88	1.00												
6. #FinTech	-0.06	-0.21	-0.34	0.43	0.44	1.00											
7. Total Assets	-0.38	-0.10	-0.50	0.40	0.47	0.41	1.00										
8. Capital Ratio	0.76	0.15	0.41	-0.06	-0.11	0.03	-0.56	1.00									
9.Interest Income	-0.10	-0.01	-0.23	-0.04	0.04	0.01	0.19	-0.28	1.00								
10.Cost to Income	-0.02	-0.02	0.07	-0.08	-0.07	-0.08	0.06	-0.07	0.74	1.00							
11.Price to Book	0.58	0.63	-0.12	0.19	0.21	-0.06	-0.16	0.36	-0.11	-0.14	1.00						
12.Net Income Growth	0.50	0.69	-0.49	0.13	0.35	-0.04	0.02	0.04	0.01	0.02	0.31	1.00					
13.Debt to Equity	-0.07	-0.13	-0.01	-0.04	-0.02	0.04	-0.14	-0.05	0.10	0.06	-0.35	-0.01	1.00				
14.Volatility	-0.24	-0.47	0.47	-0.28	-0.42	0.04	-0.11	0.11	-0.04	-0.02	-0.41	-0.50	0.12	1.00			
15.Tobin's Q	0.68	0.44	0.04	0.12	0.12	0.07	-0.31	0.65	-0.12	-0.11	0.87	0.23	-0.24	-0.27	1.00		
16.Stock Returns	0.37	0.28	0.18	-0.06	-0.08	-0.31	-0.30	0.31	-0.12	-0.04	0.40	0.08	-0.22	-0.15	0.35	1.00	
17.NPL Ratio	0.34	-0.07	-0.08	-0.09	0.01	0.04	-0.03	0.38	-0.01	-0.20	-0.05	-0.06	0.20	0.21	0.13	0.10	1.00

Table 2: Effects of FinTech formation on bank risk

This table reports regression results of bank risk on FinTech and the control variable. Panel A shows the contemporaneous linear effect model results while Panel B present the non-linear model results. In these regressions, the dependent variable, RISK, represents one of the two dependent variables Z-score and Ln Z-score. The descriptions of the control variables are noted in Table 1. The estimation method is the two step GMM system dynamic panel estimator. p-values are computed by the heteroscedasticity-robust standard errors clustered at bank level. The p-value associated with the Hansen J-test for determining the validity of the overidentifying restrictions is reported. T-statistics appear in parentheses and the symbol*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: FinTech and default risk

	Z-score		Ln Z-score	
Variable	Model I	Model II	Model I	Model II
#Fin-Tech	17.74***	13.372**	0.195***	-0.422*
	3111.9	2.963	84.75	-1.997
RISKt-1	0.168***	0.192***	0.604***	0.670***
	-1123.6	5.752	534.98	9.549
Size		5.420		0.698***
		0.465		3.658
Capital ratio		-1.341		0.0507**
		-0.319		2.450
Interest income share		-0.758		-0.077**
		-0.379		-3.398
Debt Equity Ratio		-4.740		-0.1636
		-0.149		-0.721
Net income growth		-0.396		-0.017**
		-0.533		-2.623
S.E. of regression	26.77	28.98	0.606	0.538
Prob(J-statistic)	0.394	0.176	0.381	0.273
Observations	242	167	235	187
Instrument rank	19	10	19	17
Wald Test: F	33218605	6801.245	4153692	32243
Wald Test: Chi-Sq	66437211	47608.71	8307385	225701

Panel B: Non-linear effects of FinTech firms on bank risk

	Z-score		Ln Z-Score	
Variable	Model I	Model II	Model I	Model II
#Fin-Tech	37.245***	35.180*	2.608***	2.655*
	52.58307	1.888207	92.98014	2.090856
#Fin-Tech squared	-2.752***	-2.807674	-0.343***	-0.360**
	-25.13829	-1.163452	-82.03742	-2.232285
RISKt-1	0.1717***	0.191***	0.627***	0.629***
	337.6626	26.90017	474.0725	9.185714
Size		0.579297		0.094915
		0.135797		0.513704
Capital ratio		0.822139		-0.023335
		0.719794		-1.199294
Interest income share		-1.704541***		-0.0402**
		-6.40226		-2.474128
Debt Equity Ratio		1.618252		-0.222512
		0.657307		-0.759927
Net income growth		-0.297211		-0.014**
		-0.661506		-2.588061
S.E. of regression	26.73908	26.38461	0.573907	0.564784
Prob(J-statistic)	0.405526	0.463348	0.797638	0.130896
Observations	242	206	235	199
Instrument rank	19	17	20	17
Wald Test: F	2627324	821.3229	118727.3	14468.06
Wald Test: Chi-Sq	7881972	6570.583	356181.8	115744.5

Table 3: Lag effects of FinTech Formation on Bank risk

This table reports the results of the regression using the lag of FinTech formation as the main independent variable. In these regressions, the dependent variable, RISK respectively represents one of the two dependent variables Z-score and Ln Z-score. The estimation method is the two step GMM system dynamic panel estimator. The p-values are computed by the heteroscedasticity-robust standard errors clustered at bank level. The p-value associated with the Hansen J-test for determining the validity of the overidentifying restrictions is reported. T-statistics appear in parentheses and the symbol, ,*, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Z-Score		Ln Z-Score	
Variable	Model I	Model II	Model I	Model II
#Fin-Tech t-1	26.759***	48.564*	2.260427	2.545**
	116.0538	1.876105	82.43586	2.66008
#Fin-Tech t-1 Sq	-2.6204***	-5.487651	-0.308617	-0.357***
	-66.14402	-1.576628	-69.87492	-3.078228
RISKt-1	0.1455***	0.169915***	0.429951	0.481142***
	1868.769	10.78333	308.5356	4.723351
Log of total assets		-7.714045*		0.001098
		-1.658308		0.003463
Capital ratio		-0.039951		0.002359
		-0.07068		0.07849
Interest income share		-35.85885***		-0.114988
		-3.458134		-1.642873
Debt to Equity		-5.911216***		-0.4996***
		-3.154798		-3.331081
Net income growth		1.982704		-0.02183
		1.010952		-0.838357
S.E. of regression	28.06495	43.53684	0.651707	0.693987
Prob(J-statistic)	0.294014	0.417266	0.23183	0.17333
Observations	242	206	235	199
Instrument rank	19	17	20	17
Wald Test: F	2520013	414.8664	201671.1	191.9179
Wald Test: Chi-Sq	7560039	3318.931	605013.3	1535.343

Table 4: Fin-Tech and bank risk: Channels

This table reports regression results of FinTech on the default risk of bank using the components of Z-score , namely return on assets (ROA), standard deviation of ROA, and equity to total assets. The estimation method is the two step GMM system dynamic panel estimator. p-values are computed by the heteroscedasticity-robust standard errors clustered for bank level. The p-value associated with the Hansen J-test for determining the validity of the overidentifying restrictions is reported. T-statistics appear in parentheses and the symbol *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Return on Assets		SD of Return on Assets		Equity-to-asset	
Variable	Model I	Model II	Model I	Model II	Model I	Model II
#Fin-Tech	0.7986***	13.712***	0.0240	8.4767***	0.3879***	19.4926**
	7.8694	6.461952	0.4998	16.9033	6.256154	2.382418
#Fin-Tech Sq	-0.0952***	-1.1715***	-0.0884***	-0.6759***	-0.0970***	-2.6834***
	-7.457592	-4.680655	-10.629	-10.2209	-10.5129	-2.151419
CHANNEL t-1	-0.1144***	-0.1254***	0.4539***	0.4368***	0.7236***	0.5379***
	-211.5404	-5.1951***	1596.253	78.7164	464.0734	4.99131
Log of total assets		-6.7232		-4.832***		-2.825432
		-8.9791		-18.1573		-1.194665
Capital ratio (or Price-to-book ratio)		0.1225***		0.183***		2.2399**
		10.6968		22.5613		2.671788
Interest income share		0.5238***		0.0847***		-0.292954
		6.0647		8.373		-0.524763
Debt to Equity		-1.3224***		0.777***		-0.465185
		-5.2774		12.899		-0.505845
Net income growth		1.0843***		0.1592***		0.141597
		6.1524		13.154		0.723994
S.E. of regression	7.415019	8.372858	4.559634	4.57902	3.5522	4.557203
Prob(J-statistic)	0.462457	0.350245	0.405188	0.513262	0.393934	0.575369
Observations	261	221	242	206	268	174
Instrument rank	19	18	19	17	19	11
Wald Test: F	12332086	813.2275	2709075	133280.4	45016148	145091.1
Wald Test: Chi-Sq	36996259	6505.82	8127226	1066243	1.35E+08	1160729

Table 5: Differential Effect of FinTech on Large and Small Banks

This tables report regression results of the impact of FinTech firms on large and small banks using two versions of the dependent variable, Z-score and Ln Z-score. The estimation method is the two step GMM system dynamic panel estimator. p-values are computed by the heteroscedasticity-robust standard errors clustered for bank level. The p-value associated with the Hansen J-test for determining the validity of the overidentifying restrictions is reported. T-statistics appear in parentheses and the symbol *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Effect of FinTech formation on Large banks

	Contemporaneous effects of Fin-Tech		**Lag Effects**		
Variable	Z-score	Ln Z	Variable	Z-score	Ln Z
#Fin-Tech	-211.286*	-7.395912**	#Fin-Tech t-1	-189.0391**	-9.630392*
	-2.091261	-2.614119		-3.208404	-2.139427
#Fin-Tech Sq	30.57149*	0.883102**	#Fin-Tech t-1 Sq	28.52794**	1.224897*
	2.093838	2.423283		2.969895	1.863426
Prob (J-Stat)	0.336899	0.527541	Hansen	0.368385	0.524335
Wald: F	17685.62	20719.38	Wald: F	25375680	10837.71

Panel B: Effect of FinTech formation on small banks

	Contemporaneous effects		Lag Effects		
#Fin-Tech	221.9774**	12.94554	#Fin-Tech t-1	246.2775*	5.056648*
	2.347541	1.428469		1.992744	1.87972
#Fin-Tech Sq	-23.95582**	-1.971926	#Fin-Tech t-1 Sq	-29.25135**	-0.541842
	-2.319963	-1.577407		-2.363132	-1.19644
Prob (J-Stat)	0.929968	0.829874	Prob (J-Stat)	0.687141	0.279934
Wald: F	64881.13	5.47221	Wald: F	8721.147	8205.816

Table 6: FinTech formation and Default risk of Non-bank Financial Institutions and the Full sample
This table contains results of regression showing the impact of FinTech formation on the defaults risk of non-bank financial institutions and the full sample. The estimation method is the two step GMM system dynamic panel estimator. p-values are computed by the heteroscedasticity-robust standard errors clustered for firm level. The p-value associated with the Hansen J-test for determining the validity of the overidentifying restrictions is reported. T-statistics appear in parentheses and the symbol *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Non-bank Financial Institutions		**Full Sample**	
Variable	Contemporaneous	Lag	Contemporaneous	Lag
#Fin-Tech	3.6895***	3.653318*	14.5473***	19.903***
	16.003	1.8758*	13.79213	97.53225
#Fin-Tech Sq	0.9151***	0.617588	0.1958*	-1.3134***
	15.6644	1.519252	1.989996	-27.1118
RISKt-1	0.07595***	0.0561***	0.1318***	0.1711***
	52.93973	6.45608	162.663	759.9094
Log of total assets	-6.8311***	-9.0674***	-13.8253***	-4.0507***
	-48.08017	-17.59348	-36.74816	-55.12538
Capital ratio	0.05487***	0.04498***	-0.0440*	0.0589***
	59.87151	6.125941	-1.694	23.44504
Cost to income	0.01305***	-0.0858**	-0.1501***	0.2398***
	3.036356	-2.112776**	-3.216757	51.87956
Price to book	0.7568***	2.9975***	5.1797***	0.1963***
	42.60943	11.41126	22.9226	6.454291
Net income growth	0.3828***	-0.006497	-0.1924***	0.0983***
	17.25683	-0.101312	-16.8851	9.812795
S.E. of regression	20.48568	23.94952	29.53098	23.5929
Prob(J-statistic)	0.507108	0.86601	0.396663	0.557012
Observations	363	363	554	554
Instrument rank	46	40	55	57
Wald Test: F	8185.067	360.2957	398868.2	556513.6
Wald Test: Chi-Sq	65480.54	2882.366	3190945	4452109

Table 7: Effects of FinTech Firms on the performance of Financial Institutions

This table reports the results of regressions showing the impact of FinTech formation on financial institution performance. Performance represents one of the three different dependent variables, namely ROA, Stock Returns, and Tobin's Q. The estimation method is the two step GMM system dynamic panel estimator. p-values are computed by the heteroscedasticity-robust standard errors clustered for firm level. The p-value associated with the Hansen J-test for determining the validity of the overidentifying restrictions is reported. T-statistics appear in parentheses and the symbol *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Variable	ROA	Stock Returns	Tobin's Q
#Fin-Tech (-1)	25.7116***	410.2977***	4.1239***
	92.0608	49.6395	24.9334
#Fin-Tech (-1) Sq	-2.1655***	-51.0549***	0.1219***
	-37.7536	-37.5561	4.1883
PERFORMANCE t-1	-0.2031***	-0.1241***	0.7352***
	-141.3628	-63.3625	2635.33
Log of total assets	-16.6919***	-78.9899***	-3.8173***
	-85.3219	-60.0692	-350.8797
Capital ratio	0.388***	0.8721***	-0.0252***
	190.3618	70.5818	-216.6139
Cost to income	0.4668***	1.1455***	0.0293***
	32.8383	15.4153	6.8282
Price to book	-6.2237***	-27.3498***	-0.3196***
	-80.1083	-73.5316	-189.0827
Net income growth	0.7612***	3.8914***	-0.0629***
	42.2554	24.0484	-29.623
S.E. of regression	33.84792	135.9218	11.93256
Prob(J-statistic)	0.870625	0.503684	0.910436
Observations	600	426	589
Instrument rank	57	36	55
Wald Test: F	16206345	4257208	1.12E+09
Wald Test: Chi-Sq	1.30E+08	34057666	8.97E+09

Table 8: Country Level Analysis of the effect of FinTech on Financial Institutions Stability

This table presents regression results of the effect of FinTech formation on financial institutions using aggregate (country-level) time series data. The estimation method is OLS estimator. p-values are computed by the heteroscedasticity-robust standard errors. T-statistics appear in parentheses and the symbol *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Contemporaneous effects of FinTechs			Predictive effects of FinTechs	
Variable	**Bank Z-score**	**Ln Bank Z-score**		**Bank Z-score**	**Ln Bank Z-score**
#Fin-Tech	3.2609**	0.2061**	#Fin-Tech t-1	2.4567**	0.1609**
	3.2195	3.3166		2.5255	2.7525
RISKt-1	-0.1643	-0.1073	RISKt-1	-0.0561	-0.0272
	-0.6261	-0.4566		-0.1954	-0.1078
ATM	-0.0941	-0.005035	ATM	-0.0259	-0.0009
	-1.2008	-1.0148		-0.3318	-0.1987
Domestic credit	0.0265	0.0017	Domestic credit	0.0292	0.0019
	0.8262	0.8036		0.7767	0.7886
Bank Branches	0.13	0.0029	Bank Branches	-0.1775	-0.0155
	0.2186	0.0749		-0.2745	-0.3768
Regulatory Capital	0.6559*	0.0416*	Regulatory Capital	0.5844	0.0374
	2.0831	2.0248		1.6397	1.6436
Outstanding deposits	-0.1442	-0.0134	Outstanding deposits	-0.1648	-0.0145
	-0.8707	-1.2391		-0.876	-1.2109
C	2.1582	2.1997**	C	4.5314	2.2024**
	0.1686	2.7443		0.3132	2.4717
R-squared	0.936374	0.940214	R-squared	0.917411	0.92617
Adjusted R-squared	0.872748	0.880428	Adjusted R-squared	0.834822	0.85234
S.E. of regression	0.620041	0.040705	S.E. of regression	0.706423	0.045234
Observations	15	15	Observations	15	15
F-statistic	14.71689	15.72633	F-statistic	11.10814	12.54466
Durbin-Watson stat	1.568422	1.630817	Durbin-Watson stat	1.64662	1.689597

Table 9: Robustness Tests: Controlling for the effects of the Global Financial Crisis

This table shows the lag effects of FinTech formation on financial institutions risk and performance while controlling for the effect of the global financial crises. The effect of the GFC is captured by a GFC dummy that takes a value of 1 for the years 2007 and 2008 and 0 otherwise. Panel B presents the results that show whether the effects of FinTech has changed in recent years. The dummy takes a value of 1 for the period after 2007 and 2008, and 0 before the crisis. Risk is measured using the Z-score and performance represents one of three dependent variables ROA, Stock Returns and Tobin's Q. The estimation method is the two step GMM system dynamic panel estimator. p-values are computed by the heteroscedasticity-robust standard errors clustered for firm level. The p-value associated with the Hansen J-test for determining the validity of the overidentifying restrictions is reported. T-statistics appear in parentheses and the symbol *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

	Bankruptcy Risk		**Performance**		
Variable	**Z-score**	**Ln Z-score**	ROA	Stock Returns	Tobin's Q
#Fin-Tech (t-1)	3.5345***	0.5748***	37.1688***	504.012***	3.9777***
	11.9559	6.2658	26.697	45.3367	45.9346
#Fin-Tech (t-1) Sq	0.5484***	-0.077***	-2.6664***	-60.649***	0.0851***
	9.4546	-4.6204	-10.6754	-39.0344	6.5352
Dep Var (t-1)	0.1472***	0.3027***	-0.1576***	-0.1473***	0.7383***
	167.9658	11.9695	-109.7711	-99.8586	3576.572
Log of total assets	-3.859***	0.3059***	-26.779***	-103.47***	-3.653***
	-21.8624	13.8826	-122.0451	-71.67714	-380.3494
Capital ratio	-0.090***	0.0625***	0.4584***	1.2***	-0.031***
	-19.6087	22.1944	112.4813	53.9577	-394.9345
Cost to income	-0.300***	-0.0005	0.8219***	1.6579***	0.0367***
	-19.5109	-0.589	32.5939	34.0141	11.9353
Price to book	5.2840***	0.3683***	-7.9217***	-27.467***	-0.134***
	45.2286	32.0065	-91.7899	-158.299	-89.3435
Net income growth	-0.741***	-0.015***	0.7102***	6.4852***	-0.014***
	-43.9466	-3.1479	42.5393	24.5548	-11.9142
GFC	-0.975***	-0.178***	15.0416***	23.5366***	-0.761***
	-8.1313	-7.6974	50.4037	8.5816	-23.0729
# of Observations	554	522	600	426	589
Panel B: Recency Effects-Post GFC Effects					
Variable	**Z-score**	**Ln Z-score**	ROA	Stock Returns	Tobin's Q
#Fin-Tech (t-1)	16.4167***	0.3995***	28.8948***	647.003***	2.5394***
	51.3097	3.8094	116.4924	44.8885	23.90606
#Fin-Tech (t-1) Sq	-0.9719***	-0.0515**	-2.5199***	-79.0547***	0.2441***
	-14.3312	-2.5916	-32.3513	-38.4156	13.0627
Dep Var (t-1)	0.1699***	0.2958***	-0.1820***	-0.1512***	0.7293***
	404.9582	7.3411	-185.1509	-138.718	2496.465
Log of total assets	-4.9113***	0.1138***	-20.3928***	-95.5289***	-4.5156***
	-16.4055	4.2586	-137.796	-125.8144	-407.0996
Capital ratio	0.0659***	0.0557***	0.3844***	1.0823***	-0.0206***
	10.0783	17.4265	154.2565	32.3564	-113.1508
Cost to income	0.2223***	0.0002	0.566***	1.4568***	0.0172***
	24.0176	0.1287	79.9459	23.0625	5.3965
Price to book	0.3209***	0.3546***	-6.7965***	-28.5102***	-0.2753***
	5.0159	12.5378	-155.7996	-160.2435	-131.9037
Net income growth	0.0722**	-0.0125	0.6548***	6.8615	0.0077***
	2.5791	-1.2211	43.8012	42.0824	4.291
Post-GFC	4.1916***	0.3448***	2.8867***	-55.5432***	3.4548***
	6.7268	5.8258	6.2282	-36.689***	82.1521
# of Observations	554	522	600	426	589

Table 10: Robustness Tests: Alternative measures of Risk

This table presents the results of the regression of non-performing loans, stock returns volatility and an alternative measure of Z-Score on FinTech formation and the control variables. Panel A shows the results of the alternative accounting based measures of risk, while Panel B presents the results of the market-based risk measure. The estimation method is the two step GMM system dynamic panel estimator. p-values are computed by the heteroscedasticity-robust standard errors clustered for firm level. T-statistics appear in parentheses and the symbols *, **, and *** denote significance at the 10%, 5%, and 1% levels, respectively.

Panel A: Results based on Z-Score and NPL

	Z-All (Full Sample)		**NPL (Banks)**	
Variable	Contemporaneous effect	Lag effect	Contemporaneous effect	Lag effect
Fin-Tech/Fin-Tech (t-1)	18.8365***	15.4916***	-2.9671**	-4.262*
	75.1747	20.8879	-2.4567	-1.8864
#Fin-Tech Sq/ #Fin-Tech (t-1) Sq	-2.4301***	-1.9027***	0.3131*	0.5308*
	-40.4364	-16.2173	2.0049	1.8529
$RISK_{(t-1)}$/ $Performance_{(t-1)}$	0.1288***	0.1261***	0.5232***	0.5639***
	124.5595	40.6402	35.1314	9.4778
Log of total assets	-7.011***	-9.0881***	1.4017***	1.1454***
	-31.2551	-38.92654	8.7709	3.555
Capital ratio	0.0725***	0.139703	0.2754***	0.1907***
	40.6206	27.61416	15.3135	4.0194
Interest income share/ Cost to income	0.049***	0.0791**	-2.3879**	-1.6257
	4.0723	2.6183	-2.8825	-1.2446
Price to book	0.3919***	1.6324***	0.8498***	0.7632**
	19.799	25.4083	6.7285	2.181
Net income growth	0.1208***	-0.044	-0.0352	-0.26
	3.9801	-0.5309	-0.1201	-0.6361
Observations	554	554	137	137

Panel B: Market-based measures of Risk -Return Volatility

	Banks		**Non-Bank Financial Institutions**		**Full Sample**	
Variable	Contemp. effect	Lag effect	Contemporaneous effect	Lag effect	Contemporaneous effect	Lag effect
Fin-Tech/Fin-Tech (t-1)	-44.777**	-17.6237	-25.3189***	-24.2399***	-11.2935***	-18.1819***
	-2.8757	-0.9318	-8.1425	-16.6808	-25.5962	-191.3038
Fin-Tech Sq/Fin-Tech (t-1) Sq	3.012	-0.8697	4.3453***	4.4943	2.8758***	3.5270***
	1.0167	-0.261	13.0796	15.5898	26.6496	102.9826
PERFORMANCE (t-1)	0.9338***	0.4982***	0.1504***	0.1596***	0.1758***	0.1992***
	4.6079	4.1307	20.0962	22.7032	61.9052	194.9796
Log of total assets	31.6983***	25.0941***	-1.6294	-2.0104***	-8.5599***	-4.1722***
	3.3874	3.8604	-0.9023	-2.8834	-55.1929	-33.7887
Capital ratio	1.9216***	2.5609***	0.1155***	0.1179***	0.2085***	0.0376***
	5.2492	5.7582	9.2151	14.9228	117.6509	94.4024
Interest income share/ Cost to income	1.8229	1.6026	-0.2506***	-0.2077***	-0.0036***	-0.0709***
	0.6451	0.5277	-6.1094	-7.0441	-14.8073	-19.0148
Price to book	3.9190***	4.4176**	0.4841***	0.4103***	0.1451***	-0.4163***
	4.7558	3.2519	4.3161	5.9091	11.9189	-56.22574
Net income growth	0.1401	0.5258	0.3159***	0.4435***	0.3***	0.6374***
	0.3557	0.2192	5.125	11.1076	19.9724	128.9509
Observations	169	168	379	379	576	575