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FINANCIAL TECHNOLOGY IMPACT ON STABILITY OF FINANCIAL INSTITUTIONS

Jelena STANKEVIČIENĖ*, Jelena KABULOVA

Department of Financial Engineering, Faculty of Business Management, Vilnius Gediminas Technical University, Vilnius, Lithuania

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Abstract. It is a controversial question whether financial technology makes financial institutions vulnerable (instable). This research is based on the analysis of financial institutions from 37 countries. Authors use regulatory sandboxes that are introduced in countries as an external FinTech shock to examine the impact of financial technology on financial institution stability. Some observations can be drawn: 1) if market characteristics are not considered, then there is no effect on the financial institution vulnerability linked to the shock of FinTech innovation; 2) development of FinTech in developed countries can reduce (or increase) the vulnerability (instability) of financial markets; 3) FinTech impacts the vulnerability (instability) of financial institutions through the profitability.

Nevertheless, these indicators do not consider the complex multidimensional essence of FinTech. This article summarises how FinTech and developed financial institutions and the financial sector are in terms of their depth, access, and efficiency. The article offers a valuable analytical means of developing FinTech impact on financial stability for researchers and policymakers.

Keywords: financial stability, FinTech, financial indicators, financial market, z-score.

JEL Classification: F65, G21, G28, O33.

Introduction

The outstanding hop and the disruptive power of the emerging technological development in finance have questioned the existing regulatory and institutional structures in the financial sector (Pollari & Ruddenklau, 2021). FinTech investments across the globe reached $33.4 billion in H1'21. Obviously, FinTech offers new and transforms existing models of financial service companies, providing further potential for FinTech start-up companies. Today's financial markets witness the different applications of FinTech, from crowdfunding, peer-to-peer lending (P2P), smart contracts, and Robo-advising to probably best-known applications in cryptocurrency. In recent research and reports, FinTech is increasingly being described as

*Corresponding author. E-mail: *jelena.stankeviciene@vilniustech.lt*

an application of technological innovation in financial markets (Financial Stability Board, 2019; Giglio, 2022; Haddad & Hornuf, 2019; Schueffel, 2017; The Bank for International Settlements [BIS], 2020).

Authorities across the globe have embraced different initiatives to keep up-to-date on the prompt technological development and facilitate the development of different FinTech ecosystems. This article analyses the introduction of FinTech innovation Centers with regulatory sandboxes as part of the all-around strategies sought by authorities as a reaction to the FinTech development.

Most of the studies that try to deal with the idea of FinTech sector development causing the instability of the financial sector focus on relatively narrow FinTech categories failing to look over the comprehensive effect. At the moment of writing this article, there was no significant research that directly addressed the issue of FinTech innovation development disrupting financial stability. In the research literature on FinTech impact on the stability of financial institutions, there is an obvious gap.

The authors of this paper do not pose to provide a comprehensive comparison among the numerous known models, and it inevitably contains a certain level of generalisation. The primary objective is to determine particular key aspects of the structure and functional parameters of innovation enablers, which are appropriate in the context of the potential benefits and risks related to their function. Furthermore, for policymakers' consideration from a market perspective, this paper points to specific components in assessing the impact and the possible outcomes of the activities of innovation enablers globally and of improving the supervisory intersection.

At one end of the spectrum, FinTech could increase market volatility and threaten financial stability. At the other end of the spectrum, it could diminish the potential risk to financial stability through increased transparency, diversification and decentralisation of financial services. It is becoming increasingly clear that FinTech may have different effects on the financial institution's stability, both positive and negative. Though data available on FinTech innovation is still rather limited, further presented research is analysing FinTech innovation Centers through the launch of the regulatory sandboxes.

A FinTech sandbox is an environment that innovators can use to copy the characteristics in place of the environment on a real-time basis to help simulate reactions from all aspects of the ecosystems. This grants banks and FinTech companies the possibility to experiment with innovative financial products and services within the bounds of controlled and regulated space. Essentially, the sandbox allows for the pilot testing of newly developed technologies (PwC, 2020).

With this in mind, the launch of the FinTech sandbox can be presented as a positive shock to the development of FinTech innovation. It can be used to probe its impact on the stability of financial institutions.

The aim of the study is to provide a comprehensive analysis and evidence of the FinTech impact on the stability of the financial institution.

The structure of this paper is as follows: chapter 1 gives a relevant set of literature background to define the role of innovation enablers in the financial sector, to provide a wider perspective. It shortly summarises the challenges and complexities brought by FinTech, in certain the vast variety of companies, products, and business models, as well as the new or adjusted risks they provoke and summarises the major research carried out in this area up to date. Chapter 2 provides an overview of the used methodology and data for analysing main types of innovation centres – and their dissemination around the globe. Moreover, it gives the primary expected advantages and the possible risks arising from innovation centres. Chapter 3 presents results and discussion that focus on the main structure and functional aspects of FinTech Centers, which are needed to optimise their benefits while minimising the potential risks and possible limitations. Chapter 4 completes the analysis with the main findings of the study.

This paper exploits a number of various research articles and financial and analytical reports. The results of this study can be used for the further analysis of the reaction of financial institutions to FinTech innovation.

1. Literature review

In recent years, with a large body of literature dedicated to the development of FinTech, whether or not it stipulates instability in the financial sector is a topic that stimulated the concern of both industry and regulators. Nevertheless, there is limited literature on this matter. Most conducted studies and research focus on a specific category of FinTech rather than dealing with its overall impact (Financial Stability Board, 2017, 2019; International Monetary Fund [IMF], 2018). In recent years there has been no research conducted on a specific issue that would address whether or not the recent development of FinTech disrupts the financial stability of financial institutions. Considering an evident extreme phase of development of the FinTech sector and the increasing concern that authorities and regulators are expressing (Haddad & Hornuf, 2021), in research literature on FinTech impact the stability of financial institutions, there is an obvious gap.

The effect of the financial and economic crises of the 20th and 21st centuries and the development of FinTech has caused the need for the scientific community to conduct research in the field of financial sustainability at the global, international and national levels. Financial institutions, central banks, analytical companies and financial and economic experts have shown particular interest in this issue. The desire of the institutions concerned to develop appropriate approaches and methods of analysis is aimed at timely identification of sources of threats to financial stability and the development and design of a proper response to them. In other words, one of the main tasks of such work is to support the chosen strategy of action to achieve the ultimate goal. To date, the analysis of the financial stability of the economy consists of studying various kinds of interrelationships, detecting defects and negative shifts, as well as economic, regulatory and institutional indicators to evaluate the prospects for the conditions of the financial sector and its vulnerabilities.

At present, the concept of "financial stability" does not have any strict, standardised definition, aggregate indicator or system of measures used by the central banks of countries to assess the financial vulnerability (Gadanecz & Jayaram, 2009). In this regard, the monetary authorities of various countries have a wide range of tools for determining the stability of financial systems, the construction of which is based on the analysis of quantitative indicators of financial reliability and stability, reflecting the national characteristics of economic development. Among the most significant practical tools are, as a rule, statistical, economic-mathematical and econometric models (IMF, 2019). Of course, each of them can have its own advantages and disadvantages, but at the same time, they can effectively complement each other.

To consider financial stability as a systemic event within a particular location or region, in world practice, it is common to use a certain set of indicative indicators reflecting the location of not only the institutions of the financial sector, infrastructure and the market as a whole but also the real, state, external sectors of the economy. Thus, it considers changes in the macroeconomic conditions that have a notable effect on the state of the financial industry.

Among the most interesting about the development of indices and approaches to assessing financial stability, it is necessary to highlight the following studies. Monin's work (Monin, 2019) describes approaches to constructing a stress index of financial stability. In another study conducted by Ivashenko et al. (2016), the problem of creating a composite index of leading indicators for a country was solved, which can be used as a tool for making economic decisions in real-time. Sviderskaya and Miksyuk (2012) analysed the methodology for constructing systems of leading indicators for the country's economy, highlighting the most effective ones. Further, on their basis, a composite index was formed to predict the tension in the country's foreign exchange market. Vlasenko (2013) studied the issue of obtaining a comprehensive assessment of systemic risk, which makes it possible to characterise the dynamics of factors and threats to macro-financial stability, as well as to analyse the exposure of the country's banking sector and the economy as a whole to systemic risk over time.

In determining the set of indicative indicators, the researchers relied on international experience accumulated in the field of financial stability (Albulescu et al., 2013; Gersl & Hermanek, 2007). In turn, the search for factors that play an essential role in assessing financial vulnerability using economic and mathematical research methods began to develop in the 1990s, explained for two reasons. First, establishing the relationship between indicative indicators and the vulnerability of the financial system using mathematical and statistical methods requires a relatively long series of observations. Secondly, there was the need for preliminary development of a methodology for researching financial stability and identifying the causes of financial crises (Arner et al., 2015).

An analysis of the literature devoted to the search and study of indicators that characterise or predict the onset of crisis phenomena suggests that researchers are faced with several difficulties:

1. First, there are many definitions of financial shocks and crises.
2. Secondly, crisis phenomena may differ depending on the type, country (economy) of manifestation, and the period of their implementation. In this regard, research results can often differ and do not have the same conclusions.
3. Third, and most importantly, in the process of empirical research in identifying indicators – harbingers of the crisis, they face the problem of sample bias.

The studied indicators are selected based on retrospective analysis and, as a rule, consider the logical conclusions of economic theory. Even if the chosen indicators are determined to be statistically significant, their usefulness may turn out to be conditional if the indicator gives a signal after the onset of the crisis.

At the end of the 20th century, researchers began to actively use aggregate indicators of the banking system and macroeconomic indicators in order to build an aggregate financial stability index (hereinafter referred to as AFSI), which would allow assessing the conditions of the financial system of the country and could also be integrated into early warning systems as a leading indicator. An analysis of empirical studies shows that when constructing an AFSI to assess financial stability, identify factors that cause the development of instability, as well as predict the development of processes in terms of financial stability, models of leading indicators, binary choice, regression analysis, etc. are used, as a rule. Below we will consider the most popular approaches and models.

2. Data and methodology

The panel sample was drawn from the Thomson Reuters Datastream (TRD) and included data on banks listed in the time period between 2015–2019. The data for 2015 were excluded, as a FinTech sandbox framework was first introduced in the United Kingdom by the Financial Conduct Authority in 2015. So, the data before 2015 is not relevant and fitting for this research. Data on Bank characteristics is also drawn from TRD. The extensive dataset of financial system characteristics is drawn from the World Banks' Global Financial Development Database. The macroeconomic dataset was drawn from the World Banks' World Development Indicators. All data of three categories of characteristics are combined. The ultimate panel sample was composed of 7632 year observations for financial institutions from 37 countries. The detailed statistics for all three categories of indicators (company, market, macroeconomic) are presented in Table 1 (Tier 1, Tier 2, Tier 3). Allocation of observations by year and country is presented in Tier 4. It can be pointed out that the dataset is reasonably scaled across selected countries and defined period: 19.180% to 21.897% of the total early observations.

2.1. Basic empirical model for financial stability

To assess the impact of FinTech's innovation on the stability of financial institutions, we are taking advantage of the external and as defined before – positive shock as a result of FinTech innovation originating from the development of the FinTech sandbox. The following regression is calculated for the company, market, macroeconomic indicators:

$$FS_{ijt} = \beta_0 + \beta_1 S_{it-1} + \beta_2 \beta F_{jt-1} + \beta_3 M_{it-1} + \beta_4 N_{it-1} + y_t + c_j + e_{ijt}, \quad (1)$$

where: FS – financial stability; S – FinTech sandbox; F – company indicators; M – market indicators; N– macroeconomic indicators; i – country; j – financial institution; t – year; y – year effect (fixed); c – company effect (fixed); e – error term.

To account for the upward trend of FinTech innovations, the year fixed effects are introduced into the equation. The company fixed effect – for static (invariant regarding time) company indicators. In this model, a one-year lag inevitably occurs for the reason of data timing mismatch: variables of the stability of financial institutions (banks) are measured during year t, and variables drawn at the end of the period of $t-1$ from actual results. FinTech Sandbox is a variable where if the analysed country has introduced a sandbox at the year t-1, it equals one and if not – 0. Such similar models for the valuation of financial stability can be found in other studies (Fazio et al., 2018; Goetz, 2018).

Table 1. Descriptive statistics of the financial institution, market and macro-economic country-level indicators

Variable	No	Mean	St. Dev.	25%	50%	75%
Tier 1 Financial institution indicators						
Fintech Sandbox	7630	0.01	0.08	0	0	0
Bank's Non-Interest Income to Total Income	7617	0.12	0.23	0.23	0.30	0.21
Book-to-Market Ratio	7628	1.45	1.13	0.30	0.74	1.60
Capital Growth	7630	0.09	0.15	0.03	0.05	0.03
Leverage	7574	0.38	0.13	0.22	0.41	0.56
Log (assets)	7630	16.45	2.38	13.50	16.95	19.18
Log (z-score)	5271	2.44	1.01	1.76	2.51	3.21
Short-term debt to total assets ratio	7427	0.05	0.09	0	0.01	0.04

Variable	No	Mean	St. Dev.	25%	50%	75%
Tier 2 Market indicators						
Depth of financial market	7127	9.74	10.34	1.37	7.613	15.66
Access to financial market	7263	25.81	16.17	13.15	23.56	25.76
Efficiency of financial market	7588	2.11	1.62	2.05	3.22	2.54
Financial Inclusion Index	6636	0	39.78	28.85	1.09	18.88
Stability of financial institution	7021	32.69	33.71	0	32.92	59.44

Variable	No	Mean	St. Dev.	25%	50%	75%
Tier 3 Macroeconomic indicators						
(%) GDP growth	7456	1.82	1.50	1.59	1.26	2.86
(%) GDP growth volatility	7456	1.42	1.41	0.36	0.71	1.48
(%) Log (GDP per capita)	7456	8.86	1.44	8.98	9.82	9.92

Tier 4 Distribution of observations by year, region and country (%)							
Country	City	2015	2016	2017	2018	2019	Total
Europe							
United Kingdom	London, Edinburg	0.54	0.46	0.54	0.55	0.45	2.54
Switzerland	Zurich, Geneva	0.45	0.46	0.54	0.57	0.51	2.53
Germany	Berlin, Frankfurt	0.36	0.63	0.41	0.44	0.77	2.61
France	Paris, Nice	0.54	0.60	0.68	0.43	0.75	2.99
Sweden	Stockholm	0.54	0.50	0.41	0.45	0.39	2.31
Netherlands	Amsterdam, Rotterdam	0.48	0.63	0.39	0.40	0.68	2.57
Ireland	Dublin	0.30	0.51	0.65	0.39	0.75	2.60
Russia	Moscow, St.Petersburg	0.51	0.53	0.38	0.48	0.76	2.65
Spain	Barcelona, Madrid	0.49	0.50	0.64	0.66	0.52	2.81

End of Table 1

Italy	Milan, Rome	0.29	0.56	0.43	0.57	0.41	2.25
Poland	Warsaw	0.48	0.69	0.61	0.40	0.46	2.64
Lithuania	Vilnius	0.51	0.61	0.50	0.66	0.64	2.92
Belgium	Brussels	0.46	0.55	0.39	0.54	0.72	2.67
Austria	Vienna	0.45	0.46	0.37	0.69	0.76	2.72
Turkey	Istanbul	0.33	0.43	0.49	0.55	0.40	2.21
Africa							
South Africa	Cape Town	0.44	0.48	0.44	0.68	0.73	2.94
Kenya	Nairobi	0.34	0.51	0.61	0.38	0.46	2.29
Agypt	Cairo	0.32	0.58	0.69	0.44	0.41	2.43
Australia							
Australia	Sydney, Melbourne	0.44	0.59	0.59	0.47	0.65	2.73
Asia							
China	Beijing, Shanghai, Shenzhen, Guangzhou, Hong Kong, Nanjing, Chengdu, Chongqing, Xi'an	0.29	0.43	0.64	0.61	0.62	2.59
Singapore	Singapore	0.34	0.37	0.40	0.68	0.52	2.31
Japan	Tokyo	0.42	0.47	0.66	0.39	0.76	2.69
South Korea	Seoul	0.49	0.47	0.40	0.43	0.61	2.39
Indonesia	Jakarta	0.44	0.40	0.44	0.41	0.43	2.12
Vietnam	Ho Chi Minh	0.48	0.67	0.52	0.42	0.52	2.60
Malaysia	Kuala Lumpur	0.43	0.69	0.69	0.59	0.40	2.83
UAE	Abu Dhabi, Dubai	0.52	0.39	0.63	0.66	0.64	2.84
Thailand	Bangkok	0.51	0.69	0.51	0.69	0.50	2.89
Philippines	Manila	0.30	0.46	0.71	0.48	0.45	2.41
Pakistan	Karachi	0.44	0.63	0.68	0.47	0.70	2.93
India	New Delhi, Mumbai, Bangalore	0.42	0.42	0.39	0.39	0.73	2.35
Israel	Tel Aviv	0.36	0.54	0.68	0.68	0.61	2.87
Americas							
USA	New York, San Francisco, Chicago, Atlanta, Seattle, Boston, Los Angeles, Washington, Philadelphia, Miami, Las Vegas	3.57	0.71	0.44	0.56	0.70	5.97
Brazil	Sao Paulo, Rio de Janeiro, Brasilia	0.52	0.70	0.37	0.39	0.51	2.49
Mexico	Mexico	0.56	0.50	0.50	0.46	0.70	2.73
Argentina	Buenos Aires	0.48	0.51	0.59	0.64	0.68	2.90
Canada	Toronto, Montreal, Vancouver,	0.36	0.64	0.69	0.51	0.61	2.81
	Total (%)	19.18	19.96	19.74	19.22	21.89	100.00

In the above-presented set of tables, the proposed regression analysis uses descriptive statistics for a company-, market, and macroeconomic-level indicators. The selected period of time includes data from the years 2015 to 2019. Financial institutions (banks) listed in TRD are included in the calculation. Company-, market, macroeconomic-level indicators were drawn from TRD, the World Banks Global Financial Development Database and World Development Indicators. As proposed by Svirydzenka (2016), the depth, access, efficiency and stability of financial institutions (banks) were measured using bank assets to GDP, bank branches per 100,000 adults, net interest margin, provisions to non-performing loans. Market-level indicators were defined in Financial Inclusion Index.

2.2. Measuring stability of financial institutions

Institution-specific data was drawn from TRD. After cleaning the sampled data for a specified time period of missing balance sheet data or missing observations for country-level data, the final sample from 2015–2019 (5 years) included 4346 banks in 37 countries with a total number of 98 thousand observations.

This data was used to evaluate financial stability. When measuring bank financial stability, many studies in scientific literature use the Z-score (Beck et al., 2013; Fang et al., 2014; Goetz, 2018; Köhler, 2015; Laeven & Levine, 2009). The literature is vast, and it is known that the Z-score can, on average, predict 78% of failures of financial institutions (banks) (Chiaramonte et al., 2016; Uddin et al., 2020). Z-Score can be explicated as the number of standard deviations profits a financial institution can lose before going bankrupt. The natural logarithm of the Z-score is used to analyse financial stability:

$$z - score_{jt} = \frac{ROA_{jt} + CAR_{jt}}{\sigma\left(ROA\right)_{jt}}, \quad (2)$$

where: j – financial institution; t – year; ROA – return-on-assets; CAR – capital-asset-ratio; σ (ROA) – standard deviation of return-on-assets.

A lower value of the z-score suggests greater instability of financial institutions (banks). Calculated z-score results in high skewness, so a natural logarithm is applied to flat out extreme deviation in values. The results presented in Table 1, Tier 1, show that the mean log (Z-score) is 2.440 and the St. Dev. – 1.005. The results of this study on statistics of the z-score substantially deviate and correlate with others presented in related literature (Eichler et al., 2018).

Using a z-score, a FinTech impact on financial stability can be measured and analysed via ROA – profitability, CAR – capital sufficiency and σ(ROA) – asset portfolio risk.

2.2.1. Financial institution-level indicators

As is proposed in related literature, to control the impact of institutional characteristics on the stability of financial institutions, different control variables are integrated into the calculation.

First, a sandbox is included to examine the external positive shock to FinTech innovation. It is a dummy indicator equal to one if country c has set the regulations during the time period t. If the negative effect of FinTech innovation outweighs the positive effect – then developing FinTech innovation increases the instability of financial institutions, and the coefficient estimated for β_1 is expected to be statistically significant and negative. On the other hand, if the positive effect outweighs the negative, FinTech innovation decreases financial institutions' instability. But if Positive and negative effects balance each other out, then this coefficient is expected to be statistically insignificant.

The second indicator included in the calculation is expected to effect financial institutions' (banks) risk. It is called the book-to-market ratio – it represents an equity's book value to the market value ratio. Prior research suggests that there is a negative correlation between the book-to-market ratio and returns of financial institutions that have elevated book-to-market ratios bear more significant risks in times of financial crisis (Aebi et al., 2012; Atkeson et al., 2019; Begenau, 2019).

Third, non-interest income was included as a variable to measure income diversity. Results show that the higher is non-interest income share to trading practice, the lower are assets and risk of default. But on the other hand, financial institutions are less risky and more stable if they have a high revenue concentration.

Fourth, leverage is included and is represented as a ratio of financial institutions' debt to their capital. Leverage impacts financial institutions' characteristics in a time of crisis. So, when faced with a crisis, institutions with high leverage bear greater instability.

Fifth, to consider a systemic risk, financial institutions' size is the main indicator and is measured by total assets. It can be stated that large financial institutions act as the main factor of systemic losses when dealing with extreme negative financial shocks. Logarithmic transformation was used to balance out highly skewed values of total assets.

Sixth, the short-term debt to total assets ratio was selected to show the link between the financial institutions' vulnerability and short-term debt.

2.2.2. Market-level indicators

Market characteristics significantly impact the stability of financial systems and are included in the framework as variables. Based on the International Monetary Fund's Working Paper on a New Broad-based Index of Financial Development, we add depth, access, efficiency and stability of financial institutions (banks) (Svirydzenka, 2016). Market-level indicators are calculated using an extensive data set drawn from the Global Financial Development Database on a country level. To maintain a comprehensive impact viewpoint of market-level indicators, Financial Inclusion Index is concluded.

2.2.3. Macroeconomic-level indicators

GDP growth and its volatility as control indicators were used to manage the impact of macroeconomic factors.

The research literature widely recognised the impact of these indicators on financial institutions' stability. For example, Delle Monache, De Polis, and Petrella (2021) state that declining GDP increases financial institutions' sensitivity to risk, and Stewart and Chowdhury (2021) declare that lower GDP growth, together with other factors, can be the cause of financial institutions falling into a state of the distress. To add to all the findings mentioned above, the natural logarithm of GDP per capita was added (Hodula, 2022).

3. Empirical analysis

3.1. Base results

The baseline model is estimated in regression, and its results are provided in Table 2. The market, bank, and sandbox dummy characteristics are included in the first column, while in the second column, the market characteristics are replaced with the Financial Inclusion Index (FII). In columns three and four, the macroeconomic indicators are added. All used regressions include fixed effects of company and year, and standard errors are clustered by company.

There is no statistical significance of the estimated indicator for the sandbox variable in none of the used regressions. Such a particular fact implies that the establishment of the FinTech sandbox itself has no substantial impact on the stability of financial institutions (following the operation for company and market indicators), bank-specific variables (which are time-invariant), time-specific variables (which are financial institution invariant) and macroeconomic factors. Although there is a possibility of a positive/negative impact of FinTech on financial stability, the obtained outcomes show that these positive/negative sides of FinTech cancel each other.

An alternative method of z-score calculation was used for robustness. The standard deviation of return on assets (ROA) within five years in the denominator was replaced with three years. Such replacement allows a variate time in the denominator and prevents the deviation in the z-score from operating mainly through deviations in capital asset and profitability ratio. Such a method is rather usual in the literature regarding financial institutions. The regression analysis is repeated with the revised z-score, and similar results are obtained.

Control variables have interesting effects results on financial stability. In that perspective, asset growth is associated with a higher risk in the banking sector when more aggressive expanding banks are being analysed. Furthermore, financial institutions (banks) with a high ratio of D/C (debt to capital) are considered to be of a higher risk than those with a low D/C ratio. These findings align with the results presented by other authors in the research literature (Hugonnier & Morellec, 2017). According to the observation, large financial institutions are riskier than their smaller analogues, which supports the story of a "too big to fail". This mostly means there is a perception that governments will bail out large banks in the times of the crisis.

Among others, there are two market characteristics related to financial institutions' risk significantly. There is a negative link between the stability of financial institutions (banks) and their access to them. This points out that financial institutions operating in the markets with more straightforward access tend to have riskier banks. Such a statement is coherent with findings previously presented in the literature, which state that greater financial inclusion increases risk, driven by quick credit growth in the market. We also have to point out that stability of financial institutions and their depth are positively linked. This also confirms that a significant increase in reserves (based on financial depth) is crucial for financial stability.

Table 2. Introduction of FinTech sandboxes (regression of z-score)

Variable	Variable (dependent)			
	Log (z-score)			
	I	II	III	IV
Tier 1 Financial institution indicators				
FinTech Sandbox	−0.05 (−0.22)	−0.11 (−1.18)	−0.02 (−0.02)	−0.13 (−0.58)
Bank's Non-Interest Income to Total Income	1.68 (0.99)	0.85 (1.40)	0.67 (1.14)	0.77 (1.31)
Book-to-Market Ratio	−0.02 (−1.01)	−0.02 (−0.81)	−0.02 (−0.60)	−0.01 (−0.82)
Capital Growth	−0.02*** (−2.53)	−0.01 (−1.33)	−0.018*** (−2.05)	−0.01* (−1.83)
Leverage	−0.37** (−2.12)	−0.36* (−1.83)	−0.36** (−2.11)	−0.31* (−1.64)
Log (assets)	−0.15** (−2.18)	−0.34*** (−3.75)	−0.18 (−1.51)	−0.23*** (−2.46)
Short-term debt to total assets ratio	0.22 (0.38)	0.23 (0.37)	0.11 (0.15)	0.02 (0.02)
	I	II	III	IV
Tier 2 Market indicators				
(%) Depth of financial institution	0.03*** (7.82)		0.03*** (7.48)	
Access to financial institution	−0.01*** (−2.84)		−0.01*** (−2.81)	
(%) Efficiency of financial institution	−0.02 (−1.13)		−0.03 (−1.34)	
Financial Inclusion Index		−0.01** (−2.25)		−0.01** (−2.24)
(%) Stability of financial institution	0.01 (0.08)		0.01 (0.08)	
	I	II	III	IV
Tier 3 Macroeconomic indicators				
(%) GDP growth			0.01 (0.81)	0.02** (2.49)
(%) GDP growth volatility			0.02 (1.29)	−0.01 (−0.15)
(%) Log (GDP per capita)			−1.04* (−1.63)	−1.73*** (−2.83)

End of Table 2

	I	II	III	IV
Fixed effects: Company Year	 X X	 X X	 X X	 X X
R^2	0.68	0.67	0.68	0.67
No of observations	3749	3749	3749	3749

Note: Variation amount of market characteristics between the components are grouped as follows: The first component – 82%, second, third and fourth components together account for the left 18%. The 2015 to 2020 period is being sampled. Banks were included according to the Thomson Reuters Datastream for that period. The natural logarithm of the z-score is a dependent variable. It is a measure of financial institutions' fragility that is usually considered in the literature on the banking sector. At the level of individual institutions, Z-score is a commonly used measure of stability. It precisely compares buffers (capitalisation and returns) with risk (volatility of returns) to evaluate a financial institution's (bank's) solvency risk. Z-score is defined as: $\frac{ROA+CAR}{\sigma(ROA)}$. Here ROA indicates the return on assets, CAR – the capital-asset ratio, and σ(ROA) – the standard deviation of return on assets over five years. Z-score has a strong evident (negative) relationship to the likelihood of a financial institution's insolvency, that is, the likelihood that the value of its assets becomes lower than the value of its debt. Therefore, a higher z-score indicates a lower likelihood of insolvency. Data for the financial institutions, economic factors, and market characteristics were obtained from the Thomson Reuters Datastream, Global Financial Development Database, and World Development Indicators (World Bank maintains two of the latter databases). To calculate access, depth, efficiency and stability of financial institutions, we use the following parameters (respectively): bank branches per 100000 adults, bank net interest margin, central bank assets to GDP, and provisions for non-performing loans. Here, the first main element of the variables of market indicators is the Financial Inclusion Index.

3.2. Internal effect of FinTech sandbox development

The assumption was formed in an empirical model that the development of a FinTech sandbox negatively correlates with indicators such as market characteristics, level of FinTech penetration, institutional characteristics, and macroeconomic factors.

Firstly, the Hausman specification test is used to test for the potential endogeneity. Market characteristics are captured by evaluating the following components: Depth of financial institutions, Access to financial institutions, Efficiency of financial institutions, and Stability of financial institutions. Tier 3 – macroeconomic indicators are captured by evaluating GDP growth, its volatility, and Log (GDP per capita) variables. These components are used as the indicators for the Hausman Test (also called the Hausman specification test), which catches endogenous regressors (predictor variables) in a regression model. FinTech Adoption Index (developed by Ernst & Young) is included as a model for addressing the impact of FinTech adoption on the likelihood of a sandbox development. This index is constructed by executing 21,424 interviews regarding the adoption of FinTech products and services in 37 countries (Ernst & Young, 2017).

The next step is to analyse whether or not the development of FinTech sandboxes is endogenous. For that likelihood ratio test and internal impact pattern is considered. For regressions to be run simultaneously, a two-equation system is used. The results of the test are presented in Table 3.

$$S_{it-1} = \lambda_0 + \lambda_1 \varphi M_{it-1} + \lambda_2 \varphi N_{jt-1} + \lambda_3 F_{it-1} + \lambda_4 A_{it-1} + e_{ijt}, \quad (3)$$

where: S – FinTech sandbox; φM – PC1 of market indicators; φN – PC1 component macroeconomic indicators; F – company indicators; A – FinTech adoption index; i – country; j – financial institution; t – year; y – year effect (fixed); c – company effect (fixed); e – error term.

Table 3. FinTech sandboxes introducing internal impact (regression of z-score)

Variable	Variable (dependent)			
	Log (z-score)			
	I	II	III	IV
Tier 1 Financial institution indicators				
FinTech Sandbox	0.24 (0.49)	0.19 (0.24)	0.24 (0.48)	0.15 (0.21)
Bank's Non-Interest Income to Total Income	0.22 (0.82)	0.21 (0.77)	0.11 (1.02)	0.11 (0.59)
Book-to-Market Ratio	0.03** (-2.26)	–0.03** (–2.42)	–0.03** (–2.45)	–0.03** (–2.75)
Capital Growth	0.44*** (6.19)	0.52*** (6.72)	0.42*** (5.86)	0.45*** (6.08)
Leverage	–0.55*** (–4.52)	–0.64*** (–5.19)	–0.51*** (–4.23)	–0.48*** (–4.17)
Log (assets)	–0.22*** (–9.13)	–0.25*** (–10.5)	–0.22*** (–9.05)	–0.23*** (–9.61)
Short-term debt to total assets ratio	0.24 (1.11)	0.04 (0.15)	0.18 (0.55)	0.02 (0.10)
	I	II	III	IV
Tier 2 Market indicators				
(%) Depth of financial institution	0.02*** (10.76)		0.02*** (8.18)	
Access to financial institution	–0.01*** (–2.89)		–0.01*** (–1.33)	
(%) Efficiency of financial institution	–0.20*** (–2.74)		–0.20*** (–2.72)	
Financial Inclusion Index		–0.002** (–2.25)		–0.002** (–2.24)
(%) Stability of financial institution	0.0004 (0.25)		0.0001 (0.18)	
	I	II	III	IV
Tier 3 Macroeconomic indicators				
(%) GDP growth			0.01 (0.89)	0.02*** (1.51)
(%) GDP growth volatility			–0.01 (–0.33)	–0.07*** (–2.79)
(%) Log (GDP per capita)			–1.69*** (–2.58)	–1.43*** (–2.79)

End of Table 3

	I	II	III	IV
Fixed effects: Company Year	 X X	 X X	 X X	 X X
No of observations	2237	2237	2237	2237
t-statistics LRT	0.11	0.07	0.28	0.06
p-value LRT	0.54	0.68	0.43	0.70

Note: Variation amount of market characteristics between the components are grouped as follows: The first component – 82%, second, third and fourth components together account for the left 18%. The 2015 to 2020 period is being sampled. Banks were included according to the Thomson Reuters Datastream for that period. The natural logarithm of the z-score is a dependent variable. It is a measure of financial institutions' fragility that is usually considered in the literature on the banking sector. At the level of individual institutions, Z-score is a commonly used measure of stability. It precisely compares buffers (capitalisation and returns) with risk (volatility of returns) to evaluate a financial institution's (bank's) solvency risk. Z-score is defined as: $\frac{ROA+CAR}{\sigma(ROA)}$. Here ROA indicates the return on assets, CAR – the capital-asset ratio, and σ(ROA) – the standard deviation of return on assets over five years. Z-score has a strong evident (negative) relationship to the likelihood of a financial institution's insolvency, that is, the likelihood that the value of its assets becomes lower than the value of its debt. Therefore, a higher z-score indicates a lower likelihood of insolvency. Data for the financial institutions, economic factors, and market characteristics were obtained from the Thomson Reuters Datastream, Global Financial Development Database, and World Development Indicators (World Bank maintains two of the latter databases). To calculate access, depth, efficiency and stability of financial institutions, we use the following parameters (respectively): bank branches per 100000 adults, bank net interest margin, central bank assets to GDP, and provisions for non-performing loans. Here, the first main element of the variables of market indicators is the Financial Inclusion Index.

Based on the obtained results, it can be stated that all of the calculated FinTech sandbox indicators are statistically insignificant (as Table 3 shows). That remains true even when operating for possible self-selection preference of FinTech sandbox development. The likelihood ratio test is conducted to examine the development of a sandbox that is endogenous. As a result, we determine if errors in both regressions are correlated. If the errors are correlated, there is a selection preference. After executing the likelihood ratio test and the other test p-values statistics are reported in Table 3. Obtained results show that all of the p-values are greater than 0.1.

After obtaining the outcomes from the Hausman test for endogeneity and the likelihood-ratio test for the internal impact pattern, it can be stated that no hard proof was found to back the statement that the development of FinTech sandboxes is internal.

3.3. Market-specific impact of FinTech

The Base section obtained results don't back this statement that developing FinTech has a total impact on financial institutions' stability. Nevertheless, FinTech sandboxes' impact on the financial stability of financial institutions may be heterogeneous between countries. This is backed by literature, suggesting that the impact of many financial stability indicators is market-specific. As a result, in some markets, promotion of the FinTech may increase the stability of financial institutions, and in other markets, it might have the opposite effect. This is studied in the current section by adding the interaction term between market characteristics and FinTech sandbox in the first formula (1). The following regression is executed, and the results are provided in Table 4.

Table 4. FinTech sandboxes and market indicators relation (regression of z-score)

Variable	Variable (dependent)				
	Log (z-score)				
	I	II	III	IV	V
FinTech Sandbox	3.52*** (3.89)	0.47** (2.09)	1.51*** (2.84)	1.22*** (2.17)	0.11 (0.57)
Sandbox x Market indicators relation					
Sandbox x (%) Access to FI	−0.28*** (−3.02)				
Sandbox x Depth of FI		−0.26*** (−2.13)			
Sandbox x (%) Efficiency of FI			−0.56*** (−2.20)		
Sandbox x (%) Stability of FI				−0.02*** (−2.52)	
Sandbox x FII					−0.02*** (−3.15)
Financial institution indicators					
Bank's Non-Interest Income to Total Income	0.65 (0.98)	0.68 (1.17)	0. 65 (1.12)	0.64 (1.13)	0.75 (1.39`)
Book-to-Market Ratio	−0.02 (−0.93)	−0.01 (−0.56)	−0.01 (−0.65)	−0.01 (−0.66)	−0.02 (−1.10)
Capital Growth	−0.02*** (−2.86)	−0.02*** (−2.09)	−0.02*** (−2.89)	−0.02*** (−2.75)	−0.01** (−1.63)
Leverage	−0.36** (−2.03)	−0.34** (−1.82)	−0.36** (−1.72)	−0.34** (−1.91)	−0.33* (−0.89)
Log (assets)	−0.16 (−0.99)	−0.15 (−1.51)	−0.16 (−1.51)	−0.16 (−1.50)	−0.22*** (−1.74)
Short-term debt to total assets ratio	0.09 (0.18)	0.13 (0.17)	0.12 (0.18)	0.11 (0.18)	0.01 (0.03)
Market indicators					
(%) Depth of financial institution	0.04*** (7.28)	0.04*** (7.27)	0.04*** (7.29)	0.04*** (7.28)	
Access to financial institution	−0.01*** −1.87)	−0.01*** (−1.86)	−0.01*** (−1.86)	−0.01*** (−1.86)	
(%) Efficiency of financial institution	−0.03 (−1.42)	−0.04 (−1.26)	−0.04 (−1.26)	−0.04 (−1.24)	
Financial Inclusion Index					0,01** (1.79)
(%) Stability of financial institution	0.00 (0.09)	0.00 (0.09)	0.00 (0.10	0.01 (0.11)	

End of Table 4

	I	II	III	IV	V
Macroeconomic indicators					
(%) GDP growth	0.01 (0.99)	0.01 (0.88)	0.01 (0.99)	0.01 (0.99)	0.02*** (1.87)
(%) GDP growth volatility	0.02 (0.98)	0.02 (0.89)	0.02 (0.99)	0.02 (1.00)	0.02 (0.28)
(%) Log (GDP per capita)	–1.10* (–1.62)	–1.10* (–1.66)	–1.10* (–1.63)	–1.10* (–1.62)	–1.75*** (–2.86)
Fixed effects: Company Year	 X X	 X X	 X X	 X X	
R^2	0.67	0.66	0.67	0.65	
No of observations	2237	2237	2237	2237	

Note: Variation amount of market characteristics between the components are grouped as follows: The first component – 82%, second, third and fourth components together account for the left 18%. The 2015 to 2020 period is being sampled. Banks were included according to the Thomson Reuters Datastream for that period. The natural logarithm of the z-score is a dependent variable. It is a measure of financial institutions' fragility that is usually considered in the literature on the banking sector. At the level of individual institutions, Z-score is a commonly used measure of stability. It precisely compares buffers (capitalisation and returns) with risk (volatility of returns) to evaluate a financial institution's (bank's) solvency risk. Z-score is defined as: $\frac{ROA+CAR}{\sigma(ROA)}$. Here ROA indicates the return on assets, CAR – the capital-asset ratio, and σ(ROA) – the standard deviation of return on assets over five years. Z-score has a strong evident (negative) relationship to the likelihood of a financial institution's insolvency, that is, the likelihood that the value of its assets becomes lower than the value of its debt. Therefore, a higher z-score indicates a lower likelihood of insolvency. Data for the financial institutions, economic factors, and market characteristics were obtained from the Thomson Reuters Datastream, Global Financial Development Database, and World Development Indicators (World Bank maintains two of the latter databases). To calculate access, depth, efficiency and stability of financial institutions, we use the following parameters (respectively): bank branches per 100000 adults, bank net interest margin, central bank assets to GDP, and provisions for non-performing loans. Here, the first main element of the variables of market indicators is the Financial Inclusion Index.

$$FS_{ijt} = \beta_0 + \beta_1 S_{it-1} + \beta_2 \beta F_{jt-1} + \beta_3 M_{it-1} + \beta_4 N_{it-1} + \beta_5 S_{it-1} \times M_{it-1} + y_t + c_j + e_{ijt}. \quad (4)$$

All projected coefficients (from all regressions in Table 4) are negative and statistically significant.

The received results firmly indicate that FinTech impact on the financial institutions' stability is market-specific. Overall, the financial institutions' stability in developed markets improves with the promotion of FinTech.

From the empirical results presented in Table 4, it could be inquired what the specific FinTechs operating in developed markets are, resulting in improvement of the financial institutions' stability. This is assessed in the next section.

3.4. FinTech impact on the elements of z-score

For the understanding of the effect that the FinTech sandbox has on financial institutions' (banks') ability to bear risk, we break down the z-score into separate elements, which are: profitability – represented by return on assets (ROA), capital adequacy – cumulative abnormal return (CAR), and asset portfolio risk – standard deviation of ROA (σ(ROA)). This is done by tracing the research of Chen et al. (2017). Regressions presented in the first (1) and third (3) formulas are executed by substituting the log (z-score) dependent variable with return on assets, capital-asset ratio, and the standard deviation of return on assets respectively. In Table 5, the obtained results of the regressions are presented.

Table 5. Z-score indicators by developing FinTech sandboxes

	Variable (dependent)					
	I	II	III	IV	V	VI
Tier 1 Financial institution indicators	ROA					
FinTech Sandbox	−0.14 (−0.75)	4.11** (1.44)	0.38* (1.87)	1.21*** (2.17)	0.11 (0.57)	0.12 (0.68)
Sandbox x Market indicators						
Sandbox x (%) Access to FI		−0.28*** (−2.58)				
Sandbox x Depth of FI			−0.26*** (−1.53)			
Sandbox x (%) Efficiency of FI				−0.56*** (−1.70)		
Sandbox x (%) Stability of FI					−0.02*** (−2.52)	
Sandbox x Financial Inclusion Index						−0.02*** (−2.75)
Tier 2 Market indicators	CAR					
FinTech Sandbox	−0.13 (−0.41)	3.32* (1.79)	1.43** (1.23)	1.54 (1.44)	2.12*** (1.84)	0.54* (1.69)
Sandbox x (%) Access to FI		−0.47 (−1.68)				
Sandbox x Depth of FI			−0.69*** (−1.86)			
Sandbox x (%) Efficiency of FI				−0.78 (−1.48)		
Sandbox x (%) Stability of FI					0.11*** (−1.93)	
Sandbox x Financial Inclusion Index						−0.05*** (−1.98)

End of Table 5

	I	II	III	IV	V	VI
Tier 3 Macroeconomic indicators	σ(ROA)					
FinTech Sandbox	0.06 (0.53)	−0.98 (−0.88)	−0.32 (−1.31)	−0.47 (−1.12)	−0.56 (−1.23)	0.03
Sandbox x (%) Access to FI		0.09 (0.87)				
Sandbox x Depth of FI			0.24 (0.88)			
Sandbox x (%) Efficiency of FI				0.25 (0.92)		
Sandbox x (%) Stability of FI					0.02 (0.95)	
Sandbox x Financial Inclusion Index						0.02 (0.99)

Column I of Tier 1 to 3 shows that the development of FinTech sandboxes does not have any impact on the elements of the z-score (in the case of the market indicators being ignored). But, after a closer assessment of Tier 1, we can conclude that in developed financial markets, the profitability of financial institutions (banks) is increased by the development of FinTech.

Projected factors for the interaction period between market indicators and the FinTech sandbox of Tier 1, presented in columns II-VI, are negative and statistically significant. This means that if there are less than 14.68 (i.e., 4.11/0.28) financial institutions operating per 100,000 adults in the financial market, financial institutions' profitability is increased with the development of FinTech.

In Tier 2 columns II and VI, we see data suggesting that in emerging financial markets, the adequacy of the capital increases with the development of a FinTech sandbox (even though the obtained results are not definitive).

Three out of the five chosen regressions have statistically significant indicators for the specified interaction period.

When the dependent variable in Tier 3 was replaced with the standard deviation of return on assets, all the evaluated factors for the interaction period were statistically insignificant. Therefore, no significant evidence was found that the development of FinTech has an impact on the stability of financial institutions via the channels of asset portfolio risk or capital adequacy.

The question arises about improving (undermined) financial institutions stability through profitability because of developing FinTech in emerging financial markets. We want to point out the following possible explanation. One such example is the rise of crowdfunding platforms, which has provided another way to attract capital, which in turn raised several start-ups on the market. In such markets, financial institutions potentially have more customers needing a loan. The above explanations are not complete. This research grants a base for future research for examining FinTech impact on stability of financial institutions regarding profitability in evolving financial sectors.

3.5. Minimising impact of the FinTech sandbox on international financial institutions

We have to point out that for the international financial institutions included in the representative sample, the development of FinTech sandbox in the country they are operating will have an impact specifically on institutions' internal operations. For addressing this issue, we run a robustness check, which is done by reducing the impact of the FinTech sandbox for financial institutions with international operations. It is done by multiplying the FinTech Sandbox variable by subtracting foreign sales from I and dividing it by the number of total sales. The regression presented in the third formula (3) is then iterated using a modified FinTech sandbox variable. The obtained findings are shown in Table 6. Tables 4 and 6 presented noticeable similarities in regression results, indicating that our obtained base findings are not affected by financial institutions' foreign operations.

Table 6. Developing FinTech sandboxes (regression of Z-score indicators after reducing for foreign operations)

	Variable (dependent)				
	Log (z-score)				
	I	II	III	IV	V
Modified FinTech Sandbox	6.12*** (4.01)	1.14** (1.98)	1.68** (3.06)	1.40** (3.14)	0.129 (0.65)
Sandbox x Market indicators relation					
Modified Sandbox x (%) Access to FI	−0.55*** (−2.98)				
Modified Sandbox x Depth of FI		−0.39*** (−2.69)			
Modified Sandbox x (%) Efficiency of FI			−0.68** (−3.01)		
Modified Sandbox x (%) Stability of FI				−0.04*** (−3.55)	
Modified Sandbox x Financial Inclusion Index					−0.04*** (−3.74)
Tier 1 Financial institution indicators					
Bank's Non-Interest Income to Total Income	0.68 (1.08)	0.80 (1.31)	0.78 (1.14)	0.80 (1.35)	0.91 (1.52)
Book-to-Market Ratio	−0.01 (−0.66)	−0.01 (−0.68)	−0.01 (−0.69)	−0.01 (−0.68)	−0.02 (−0.89)
Capital Growth	−0.02*** (−2.87)	−0.02*** (−2.94)	−0.02*** (−2.91)	−0.02*** (−2.95)	−0.01*** (−2.00)
Leverage	−0.52** (−2.04)	−0.51** (−1.99)	−0.52** (−2.04)	−0.52** (−2.03)	−0.39* (−1.62)
Log (assets)	−0.20 (−1.58)	−0.19 (−1.59)	−0.20 (−1.58)	−0.19 (−1.59)	−0.29*** (−2.46)
Short-term debt to total assets ratio	0.09 (0.18)	0.09 (0.17)	0.09 (0.18)	0.09 (0.18)	0.08 (0.03)

End of Table 6

	I	II	III	IV	V
Tier 2 Market indicators					
(%) Depth of financial institution	0.04*** (7.97)	0.04*** (7.97)	0.04*** (7.97)	0.04*** (7.97)	
Access to financial institution	−0.01*** (−3.01)	−0.01*** (−3.00)	−0.01*** (−3.00)	−0.01*** (−3.00)	
(%) Efficiency of financial institution	−0.03 (−1.32)	−0.03 (−1.32)	−0.03 (−1.32)	−0.03 (−1.32)	
Financial Inclusion Index					−0.02** (−1.97)
(%) Stability of financial institution	0.01 (0.09)	0.01 (0.09)	0.01 (0.09)	0.02 (0.17)	
Tier 3 Macroeconomic indicators					
(%) GDP growth	0.01 (1.00)	0.01 (0.96)	0.01 (1.00)	0.01 (1.00)	0.02*** (2.69)
(%) GDP growth volatility	0.02 (0.97)	0.02 (0.97)	0.02 (1.04)	0.02 (1.00)	−0.01 (−0.17)
(%) Log (GDP per capita)	−1.04* (−0.93)	−1.07* (−1.85)	−1.06* (−1.84)	−1.07* (−1.86)	−1.75*** (−3.02)
Fixed effects: Company Year	 X X	 X X	 X X	 X X	
R^2	0.67	0.66	0.67	0.65	
No of observations	2237	2237	2237	2237	

Note: Variation amount of market characteristics between the components are grouped as follows: The first component – 82%, second, third and fourth components together account for the left 18%. The 2015 to 2020 period is being sampled. Banks were included according to the Thomson Reuters Datastream for that period. The natural logarithm of the z-score is a dependent variable. It is a measure of financial institutions' fragility that is usually considered in the literature on the banking sector. At the level of individual institutions, Z-score is a commonly used measure of stability. It precisely compares buffers (capitalisation and returns) with risk (volatility of returns) to evaluate a financial institution's (bank's) solvency risk. Z-score is defined as: $\frac{ROA+CAR}{\sigma(ROA)}$. Here ROA indicates the return on assets, CAR – the capital-asset ratio, and σ(ROA) – the standard deviation of return on assets over five years. Z-score has a strong evident (negative) relationship to the likelihood of a financial institution's insolvency, that is, the likelihood that the value of its assets becomes lower than the value of its debt. Therefore, a higher z-score indicates a lower likelihood of insolvency. Data for the financial institutions, economic factors, and market characteristics were obtained from the Thomson Reuters Datastream, Global Financial Development Database, and World Development Indicators (World Bank maintains two of the latter databases). To calculate access, depth, efficiency and stability of financial institutions, we use the following parameters (respectively): bank branches per 100000 adults, bank net interest margin, central bank assets to GDP, and provisions for non-performing loans. Here, the first main element of the variables of market indicators is the Financial Inclusion Index.

3.6. Possible alternative options for measuring the impact of financial stability

Because estimation of the z-score generally uses return on assets and capital-asset ratio, supported by generally accepted accounting principles of financial statements, the obtained base empirical results are much more appropriate for investors than authorities.

We need the means to analyse if developing FinTech improves the financial institutions' stability from the authorities' perspective. Following this goal, the dependent variable in regression presented in the third formula (3) is replaced with a risk-based capital ratio. It can be described as the total capital and total risk-weighted assets ratio estimated according to financial institutions' regulations. Financial institutions' vulnerability is assessed by authorities through their risk-based capital ratio. If the financial institution has a lower risk-based capital ratio, it draws more significant concern and requires thorough supervision from authorities.

In the first column of Table 7, the results for regression are indicated in the third formula (3), whereas the dependent variable, the risk-based capital ratio, is presented.

Table 7. Possible alternative options for measuring the impact of financial stability on the development of FinTech sandboxes

	Regression			
	Company-level	Country-level		
	Variable (dependent)			
	Financial stability indicators			
	(%) Risk-Based Capital (RBC) Ratio	(%) Capital to Risk Assets Ratio	(%) Return on Equity (ROE)	(%) Non-performing Loans to Total Gross Loans
	I	II	III	IV
FinTech Sandbox	1.77*** (4.12)	0.17 (0.30)	0.60 (0.30)	−3.21** (−3.01)
Sandbox x Financial Inclusion Index	−0.07*** (−4.02)	−0.06*** (−2.80)	−0.23** (−1.98)	0.08** (2.15)
Tier 1 Financial institution indicators				
Bank's Non-Interest Income to Total Income	6.01** (2.12)	1.76 (0.37)	2.55 (0.22)	−14.04 (−1.75)
Book-to-Market Ratio	−0.02 (−1.09)	−0.05 (−0.15)	0.42 (1.02)	−0.08 (−0.49)
Core Deposit to Total Assets Ratio	−12.52*** (−6.21)	−2.16 (−0.58)	−15.93** (−3.01)	3.89 (0.81)
Income Diversity Ratio	−1.72 (−0.97)	0.24 (0.22)	8.12 (0.96)	1.22 (0.31)
Leverage	−5.24*** (−5.35)	−2.79 (−0.98)	−20.24** (−3.03)	3.87 (1.17)
Log (assets)	−1.95*** (−3.74)	0.38 (0.61)	0.51 (1.25)	−0.58** (−3.01)
Short-term debt to total assets ratio	−4.13** (−2.01)	−4.99 (−1.04)	−9.99 (−0.63)	7.04 (0.77)

End of Table 7

	I	II	III	IV
Tier 2 Market indicators				
FII	−0.01*** (2.53)	0.01 (1.00)	0.06 (1.52)	−0.01 (−0.72)
Tier 3 Macroeconomic indicators				
(%) GDP growth	−0.04 (−0.82)	0.09 (1.33)	1.30* (2.61)	−0.71*** (−4.01)
(%) GDP growth volatility	0.22** (3.03)	0.23 (1.18)	−0.42 (−0.69)	0.82** (3.04)
(%) Log (GDP per capita)	−4.03* (−2.05)	−6.07 (−0.97)	0.81 (0.64)	−2.07*** (−4.12)
Fixed effects: Company Year	 X –	 – X	 – X	 – X
R^2	0.74	0.53	0.48	0.69
No of observations	2237	432	432	432

Note: The 2015 to 2020 period is being sampled. Banks were included according to the Thomson Reuters Datastream for that period. The natural logarithm of the z-score is a dependent variable. It is a measure of financial institutions' fragility that is usually considered in the literature on the banking sector. At the level of individual institutions, Z-score is a commonly used measure of stability. It precisely compares buffers (capitalisation and returns) with risk (volatility of returns) to evaluate a financial institution's (bank's) solvency risk. Z-score is defined as: $\frac{ROA + CAR}{\sigma(ROA)}$. Here ROA indicates the return on assets, CAR – the capital-asset ratio, and σ(ROA) – the standard deviation of return on assets over five years. Z-score has a strong evident (negative) relationship to the likelihood of a financial institution's insolvency, that is, the likelihood that the value of its assets becomes lower than the value of its debt. Therefore, a higher z-score indicates a lower likelihood of insolvency. Data for the financial institutions, economic factors, and market characteristics were obtained from the Thomson Reuters Datastream, Global Financial Development Database, and World Development Indicators (World Bank maintains two of the latter databases). To calculate access, depth, efficiency and stability of financial institutions, we use the following parameters (respectively): bank branches per 100000 adults, bank net interest margin, central bank assets to GDP, and provisions for non-performing loans. Here, the first main element of the variables of market indicators is the Financial Inclusion Index.

Results shown in the first column of the Table 7 confirm that the stability of financial institutions is improved by establishing a FinTech sandbox in the developed financial sector.

4. Discussion

This research of financial technology impact on stability of financial institutions is based on the analysis of the data from 37 countries.

In some countries the case is that, regulators do believe that such interactions as introduction of the regulatory sandboxes, innovation hubs or other forms of accelerators can be a significant source of information about the development of new or existing FinTech innovations, that is crucially important for the recognition and valuation of risk and incentives on financial stability. In a broad sense, sandboxes can be defined as frameworks set up by regulators allowing FinTech companies for testing new technologies in a controlled environment. All types of accelerators are in general means dedicated to foster cooperation and provide benefits. In a long run it is also meant to evaluate the positive or negative impact and experience.

In this paper, the focus is put on regulatory sandboxes that are introduced in countries as an external FinTech shock to examine the impact of financial technology on financial institution stability.

Based on the results of the analysis, it can be pointed out that:

– if market characteristics are not considered, then there is no effect on the financial institution vulnerability linked to the shock of FinTech innovation;
– in the developed countries introduction of FinTech innovation can have an effect on the stability of the financial market;
– financial institutions stability can be impacted by the development of the FinTech through the profitability.

Many studies concerning financial institutions' valuation of financial stability use a z-score, but its estimation usually depends on reasonable hypotheses. Some previous analyses of z-score as the denominator use a three-year standard deviation of return on assets (Moreno et al., 2021; Ruiz & Weber, 2021; Schäfer & Utz, 2021), while others – a five-year deviation (Ceylan, 2021; Toader et al., 2018; Zhao et al., 2022). Therefore, to measure financial stability, other measures are presented in this paper.

The analysis and method that was developed complements other researchers that tackle the complex multidimensional essence of FinTech. Approach used in this paper can contribute to the economic literature by giving main points of how FinTech and developed financial institutions and the financial sector are in terms of their depth, access, and efficiency. It also offers a valuable analytical means of developing FinTech impact on financial stability for researchers and policymakers.

Conclusions

There is scarce research on whether the development of FinTech innovation impacts the stability of financial institutions. Since the FinTech sandbox was first introduced in the UK, many countries have followed, and sandboxes have spawned worldwide. This study capitalises on the implementation of the sandboxes as the external shock to the development of FinTech innovations to determine the impact of FinTech on the stability of financial institutions. What is more, this impact is market-specific.

When market-level indicators are overlooked, the development of FinTech innovations does not have an overall impact on the stability of the financial institution. This can be explained by the positive and negative effects of FinTech innovations balancing each other out. Nevertheless, research presented in this article shows that financial institutions operating in emerging markets implementing the sandbox increase their financial stability through profitability.

Since results show that the FinTech impact is market-specific, the regulations and indicators should be diversified and tailored for specific FinTech frameworks. This is the critical point in policymaking. The obtained results show that the impact of development of FinTech innovations in developed financial markets diminishes stability. This means that FinTech regulations should be directed to emend the financial instability originating from the development of FinTech innovations.

For further research, the authors suggest focusing on a deeper analysis of the FinTech impact on financial stability through the link between the FinTech innovation and the profitability of the financial institutions. The conducted study presents important results that can be used for setting out policies in response to rapidly developing FinTech.

Author contributions

JS and JK conceived the study and were responsible for conceptualization, data curation, formal analysis, investigation, methodology, validation, visualization, writing original draft, review & editing.

The design and development of the data collection and analysis. TS and SS were responsible for data interpretation. MG wrote the first draft of the article.

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Authors do not have any competing financial, professional, or personal interests from other parties.

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