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MODELING THE LEVEL OF A COUNTRY'S FINANCIAL STABILITY: AN ECONOMIC AND MATHEMATICAL APPROACH

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ABSTRACT

The global nature of recent financial crises clearly demonstrates that while the integration of financial markets offers numerous benefits, it can also pose significant risks, often resulting in substantial losses in the real economy. In this context, analyzing the transformation of financial markets is essential for identifying threats, as it is characterized by persistent volatility and is vulnerable to crisis phenomena. It is equally important for developing protective mechanisms against adverse developments that do not hinder the dynamics of economic growth.

This issue becomes particularly relevant in the context of the emerging digital economy and society, where the implementation of innovative life-support models creates new channels for the transmission of systemic risks and increases the structural heterogeneity of national financial systems, thereby necessitating a corresponding enhancement of the economic and mathematical tools used to model them.

The proposed methodology employs VAR models to compare financial stability parameters. This approach reveals no universal dependencies between banking system safety indicators and key macroeconomic variables, such as GDP dynamics, interest rates, the real exchange rate, and monetary emission, across individual countries. An analysis of data from Eastern Europe, the former Soviet Union, Latin America, and Southern Europe demonstrates that: a) higher capitalization requirements generally neither increase interest rates nor negatively affect GDP dynamics; b) while a rise in non-performing loans adversely affects GDP dynamics, higher profitability of bank assets and capital has the opposite effect; and c) the short- and long-term liquidity of the banking system has virtually no impact on the macroeconomic indicators of Southern European countries, whereas these functional dependencies vary considerably across other regions.

Overall, the results demonstrate the absence of universal dependencies between specific financial stability parameters and macroeconomic indicators. This implies that prioritizing measures to enhance the anti-crisis resilience of individual countries must consider the specific characteristics of their structural frameworks.

Keywords: banks, crises, risks, financial stability, investments, GDP, real exchange rate, economic growth, panel VAR model

JEL Classification: C23, E44, G01, G21, F31, O40

INTRODUCTION

In the financial system, banks occupy a special position, whether domestic or foreign. Through their deposit operations, they effectively act as custodians of public funds and serve as the backbone of payment systems. The speed at which a bank facing bankruptcy collapses is incomparable to that of any other organization. The failure of a single bank can have a strong impact on the remaining banks, even those that are fundamentally healthy. In the era of globalization, a lack of confidence in banks within one country can rapidly spread to banks across the rest of the world.

The importance of banking safety parameters as an anti-crisis factor is emphasized in “third-generation” models of financial crises. To prevent crisis phenomena arising under conditions of imperfect financial markets that can assume a global dimension in a globalized economy, some approaches propose limiting the volume of lending to the economy. However, such measures may exacerbate crisis phenomena, as the high cost of credit resources typically constrains investment and thereby worsens the dynamics of economic growth in both the short and long term.

At the same time, an excessive monetary supply, which typically accompanies an investment boom and increased profitability of financial sector operations, can also become a source of potential problems. If the profitability of the banking system is interpreted as a sign of sectoral distortions (following H. Minsky), it may initially stimulate GDP dynamics but, over time, generate the opposite negative effect. In the post-Keynesian framework, the instability of the financial sector gives rise to crisis phenomena, with external shocks serving as catalysts for this chain of events. Initially, these shocks drive increased profitability in one of the economy's main sectors, such as the banking system and the associated real estate market, leading to the crowding out of investment from other sectors, including industry. Subsequently, speculative processes emerge, eventually culminating in a price collapse, a cascade of bankruptcies, and full-scale crisis phenomena across the entire economy.

Despite significant progress in research on financial stability, existing studies generally focus on individual aspects without adequately accounting for the interrelationships between financial stability indicators and key macroeconomic indicators in a comparative context across different groups of countries. The question of the universality of such relationships remains unresolved, necessitating the development of appropriate econometric tools based on panel vector autoregression (PVAR) models.

LITERATURE REVIEW

Financial stability has been widely studied in the international academic literature. A substantial contribution to the study of the relationship between financial inclusion and the stability of the banking system was made by Ahamed and Mallick (Ahamed & Mallick, 2019). Using an international sample of 2,635 banks across 86 countries for the period 2004–2012, they argued that expanding public access to financial services has a positive impact on the resilience of banking institutions. The authors demonstrated that financial inclusion facilitates the diversification of banks' deposit bases and reduces the concentration of systemic risks.

Hakimi, Boussaada, and Karmani (Hakimi, Boussaada & Karmani, 2022) investigated the impact of financial inclusion on bank stability in the Middle East and North Africa (MENA) region and similarly concluded that strengthening financial inclusion enhances the resilience of the banking sector. Ultimately, their findings indicate that bank stability can benefit from a stable macroeconomic environment.

Feghali, Mora, and Nassif (Feghali, Mora & Nassif, 2021) argue that inclusion through access to payment services and savings accounts has a neutral or positive impact on financial stability. In contrast, access to credit can weaken financial stability if credit growth occurs without proper consideration of borrowers' creditworthiness.

Neaime and Gaysset (Neaime & Gaysset, 2018) investigated the relationship between financial inclusion and stability in MENA countries with a focus on income inequality and poverty. Their results confirmed that expanding access to financial services contributes to reducing inequality and strengthening the resilience of the financial system. However, this effect varies depending on the country's level of economic development.

Ukrainian researchers (Shkolnyk, Kozmenko, Kozmenko, Orlov & Shukairi, 2021) demonstrate the absence of uniform global standards for measuring financial stability and propose their own methodological approach, which accounts for the specificities of national financial systems' structure and regulation. The practical value of their work lies in the development of a comprehensive toolkit for assessing financial stability that takes into account the characteristics of countries with economies in transition.

Researchers (Trinh & Tran, 2024) investigate the impact of geopolitical risks on the financial stability of banking systems across a panel of 179 countries, using a wide array of econometric methods, and document a persistent negative effect of geopolitical risks on financial stability. At the same time, they find that effective governance, financial development, and trade openness serve as key mechanisms for mitigating the negative consequences of geopolitical instability.

Using data from 15 countries in the Asia-Pacific and Middle East regions for the period 2010–2021, researchers (Pham, 2026) identify a persistent cubic (S-shaped) relationship between FinTech firms and financial stability. At low levels of fintech penetration, financial stability decreases due to intensified competition, operational risks, and limited adaptive capacity. Once FinTech companies cross the first threshold, stability improves through increased efficiency, diversification,

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and enhanced risk management. However, after the second threshold, FinTech companies again undermine stability, as excessive intensity generates complexity, cyber risks, and regulatory gaps. Institutional quality and financial efficiency reinforce both the stabilizing and destabilizing phases, acting not only as buffers but also as multipliers of systemic sensitivity.

The study (Aduba, Asgari & Izawa, 2023) offers an original examination of three financial development indicators (broad monetary supply, private lending, and bank deposits) and two conditional variables (financial performance and financial inclusion) in relation to FinTech penetration. The findings demonstrate that FinTech penetration not only stimulates financial development but also significantly influences the financial development of countries with weak financial sector performance and low levels of financial inclusion. These results carry several policy implications: first, countries with weak financial sector performance can leverage FinTech to enhance financial development; and second, appropriate policies aimed at FinTech development can promote digital financial inclusion, financial deepening, and, consequently, economic growth.

As researchers suggest (Arner et al., 2020), FinTech serves as a key driver of financial inclusion, which in turn underpins sustainable and balanced development, as embodied in the UN Sustainable Development Goals (SDGs). The full potential of FinTech to support the SDGs can be realized through a progressive approach to developing the core infrastructure necessary for digital financial transformation. Our findings suggest that this strategy is best conceptualized around four main pillars. The first pillar requires the creation of digital identification, simplified account opening, and electronic KYC systems, supported by the second pillar of open, interoperable electronic payment systems. The third pillar involves utilizing the infrastructure established in the first and second pillars to enable the electronic delivery of government services and payments. The fourth pillar, the development of digital financial markets and systems, supports broader access to financing and investment.

Ukrainian researchers (Gospodarchuk & Zeleneva, 2022) have developed a matrix of indicators for assessing the financial development of countries based on SNA-2008 data. This system encompasses all classes of financial instruments and economic sectors, facilitating objective cross-country comparisons and identifying priority areas for enhancing financial stability. The researchers concluded that the level of financial development among countries is significantly differentiated, with a gap of a thousandfold value between leaders (Luxembourg, Switzerland, the Netherlands) and outliers (India, Turkey, Russia). Furthermore, the structure of financial assets serves as a decisive indicator of a country's international position and a benchmark for the formation of strategic financial development documents.

An analysis of the scientific literature reveals that the issue of financial stability is multifaceted and necessitates a comprehensive approach that considers institutional, structural, and macroeconomic factors. Despite significant progress in research on this issue, the challenge of developing economic and mathematical models for assessing the level of financial stability remains highly relevant.

AIMS AND OBJECTIVES

The purpose of the study is to develop economic-mathematical tools for comparative analysis of the relationship between financial stability parameters and key macroeconomic indicators in the context of financial market integration and growing systemic risks.

To achieve this goal, the following objectives are addressed:

1. To substantiate the methodology for applying panel vector autoregression models (PVAR) to assess the financial stability parameters of banking systems.
2. To conduct a comparative analysis of functional relationships between financial stability indicators (capitalisation ratio, non-performing loans ratio, return on assets and equity, liquidity ratios) and GDP dynamics, interest rate, real exchange rate, and money supply for representative country groups of Central and Eastern Europe, the former Soviet Union, Latin America, and Southern Europe.
3. To identify the structural specifics of these relationships in order to formulate differentiated priorities for enhancing the crisis resilience of individual countries.

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METHODS

For the empirical evaluation of the mutual relationship between individual financial stability indicators and their determinants, we will employ a panel vector autoregression (PVAR) model. For the study, we have selected the following vectors of endogenous variables:

$$\left(rs_t, m2c_t, rerc_t,\ FSI_t^k,\ \Delta Y_t\right)', \tag{1}$$

where rs_t *– short-term interest rate (%),* $m2c_t$ *– monetary overhang, defined as the difference between the actual and equilibrium values of the money supply (%),* $rerc_t$ *– the amplitude of undervaluation (overvaluation) of the real exchange rate, determined by the difference between the actual and equilibrium values of this indicator (%),* FSI_t^k *– one of the financial stability indicators (tier1, npl, returna, returne, liquidt, liquids),* ΔY_t *– GDP growth rate (%).*

In each of the PVAR models, one of the aforementioned financial stability indicators is used: *tier1*, *npl, returna, returne, liquidt*, and *liquids*. This approach enables the assessment of the comparative effectiveness of measures to enhance the resilience of the financial system to different types of crises.

All financial and economic indicators used in the calculations were obtained from the official open-access database Financial Soundness Indicators (FSIs) of the International Monetary Fund, hosted on the World Bank Data360 platform, which covers 593 indicators across 148 economies worldwide for the period 1995–2024. The open-access nature of this source ensures the full possibility of verification and replication of the input data by any interested researcher (International Monetary Fund, 2024).

RESULTS

The global nature of recent financial crises clearly demonstrates that, while financial market integration offers numerous benefits, it can also generate substantial risks, resulting in significant losses in the real sector. Minimizing the consequences of such crises requires deep reforms of both the international financial architecture and the institutional environments of individual countries, to safeguard the stability of an increasingly financially integrated world.

Bank debts act as a major trigger for financial crises due to their vulnerability to fluctuations in stocks and other markets (Gorton, 2013). In this context, the volume of non-performing loans (NPLs) can be considered a leading indicator of crisis events. At the same time, crises themselves can substantially increase the volume of problematic debt. Equally significant risks arise from insufficient liquidity in the banking system, where depositor panic may provoke large-scale capital outflows, particularly of a short-term nature (Chang & Velasco, 2021). As demonstrated by M. Schneider and A. Tornell, illiquid banks constitute a necessary and sufficient condition for the occurrence of financial crises (Schneider & Tornell, 2024). Moreover, the soundness of the banking system may depend on macroeconomic conditions, with low GDP growth rates combined with high inflation contributing to the emergence of systemic banking crises (Demirgüç-Kunt & Detragiache, 1998).

From the perspective of the emergence and progression of crisis phenomena, which are typically identified with a significant and prolonged decline in production volumes, the behavior of the real exchange rate (RER) warrants particular attention. This indicator reflects the realities of monetary policy while simultaneously serving as a factor in economic dynamics, especially in low-income countries. A depreciation of the RER usually stimulates export volumes and limits imports; however, it can also contribute to crisis phenomena, particularly in the context of an excessive monetary supply (Reinhart, 1995).

The considerations presented above suggest a mutual relationship between financial stability parameters and the most critical macroeconomic indicators, a relationship that may be long-term in nature.

As in other studies (e.g., Kasselaki & Tagkalakis, 2013), several indicators from the corresponding IMF Financial Soundness Indicators (FSI) database were used to assess the country's financial stability parameters:

1. The ratio of capital to risk-weighted assets of the banking system (*tier1*).
2. The share of non-performing loans (*npl*).
3. Return on assets (*returna*).
4. Return on equity (*returne*).

5. The ratio of liquid assets to total assets of the banking system (*liquidt*).
6. The ratio of liquid assets to short-term liabilities (*liquids*).

There are several potential advantages to using financial stability indicators (Wilkinson, Spong & Christensson, 2010):

1. First, the information obtained allows for a better understanding of existing risks and potential issues that typically lead to financial distress and crisis phenomena.
2. Second, it places greater emphasis on risk management.
3. Third, it creates prerequisites for improved communication between central banks and the public.

The financial system's vulnerability to crisis phenomena grows gradually, primarily during the economic boom phase when confidence in the economy remains high, but it drops sharply during a recession. Typically, the sources of vulnerability include low asset quality, elevated market and credit risks, and insufficient capital of commercial banks and financial companies. Adverse accompanying circumstances may include: excessive public debt, a deteriorating current account balance, or excessive exchange rate fluctuations.

Empirical studies largely confirm the link between financial stability indicators and crisis phenomena. For instance, a study of 20 OECD countries found that during financial crises, non-performing loans (NPLs) rise sharply, while return on assets (ROA) declines (Kasselaki & Tagkalakis, 2013). An earlier study covering 96 countries for the period 1998–2005 showed that the business cycle is negatively correlated with capital adequacy and NPL ratios. In contrast, a positive correlation is observed with profitability indicators (Babihuga, 2007). Financial stability indicators also depend on the real exchange rate (RER), inflation, and interest rates. At the same time, cross-country differences in terms of income level, financial sector depth, and the quality of banking supervision exert a significant influence.

Furthermore, there is a broad consensus regarding the dependence of financial stability indicators on macroeconomic, fiscal, and institutional factors. Based on data from 25 emerging market economies for the period 1996–2010, researchers have found that the volume of non-performing loans (NPLs) increases in response to currency depreciation, deteriorating terms of trade, and declining foreign capital inflows. At the same time, no significant relationship with interest rates has been identified. Conversely, an increase in non-performing loans (or a contraction in lending) hurts economic growth dynamics (De Bock & Demyanets, 2012).

Functional relationships are estimated for several groups of countries that differ in terms of income levels, exchange rate regimes, and histories of financial crises. The CEE-4 group comprises four countries — Poland, Romania, Hungary, and the Czech Republic — all of which operate under floating exchange rate regimes. The remaining Central and Eastern European (CEE) countries, which employ various forms of fixed exchange rate regimes, are included in the CEE-11 group: Albania, Bulgaria, Bosnia and Herzegovina, North Macedonia, Slovakia, Slovenia, Montenegro, Croatia, Estonia, Latvia, and Lithuania. A comparison of functional relationships between the CEE-4 and CEE-11 groups enables the assessment of the argument regarding the greater susceptibility to crisis phenomena in countries with floating exchange rates (Claessens & Kose, 2013).

The CIS-8 group, representing countries of the former Soviet Union, includes Armenia, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Uzbekistan, and Ukraine. Data for Azerbaijan, Belarus, and Russia are unavailable in the IMF database. In Latin America, the LA-6 group comprises Argentina, Brazil, Colombia, Mexico, Chile, and Uruguay. These countries are characterized by a relatively higher susceptibility to crisis phenomena, which allows for the identification of functional relationships specific to this type of economy in comparison with other country groups under study.

Finally, to ensure the comprehensiveness of the analysis, data from four European countries commonly considered vulnerable are included: Greece, Italy, Spain, and Portugal. Greece was at the epicenter of a large-scale financial crisis between 2010 and 2014, while Spain and Portugal were long regarded as potential candidates for subsequent financial instability. Although Italy has maintained a relatively stronger financial position in recent years, it remains characterized by a high level of public debt, which increases the likelihood of crisis phenomena.

Following standard practice in similar studies, the empirical results are interpreted using impulse response functions (IRFs) obtained via Cholesky decomposition. It is assumed that, in the current period, the short-term interest rate acts as an exogenous factor directly influencing the magnitude of the monetary overhang. In turn, monetary indicators determine the amplitude of deviations of the real exchange rate (RER) from its equilibrium value. Taken together, these monetary factors influence financial stability indicators, which ultimately determine the dynamics of GDP.

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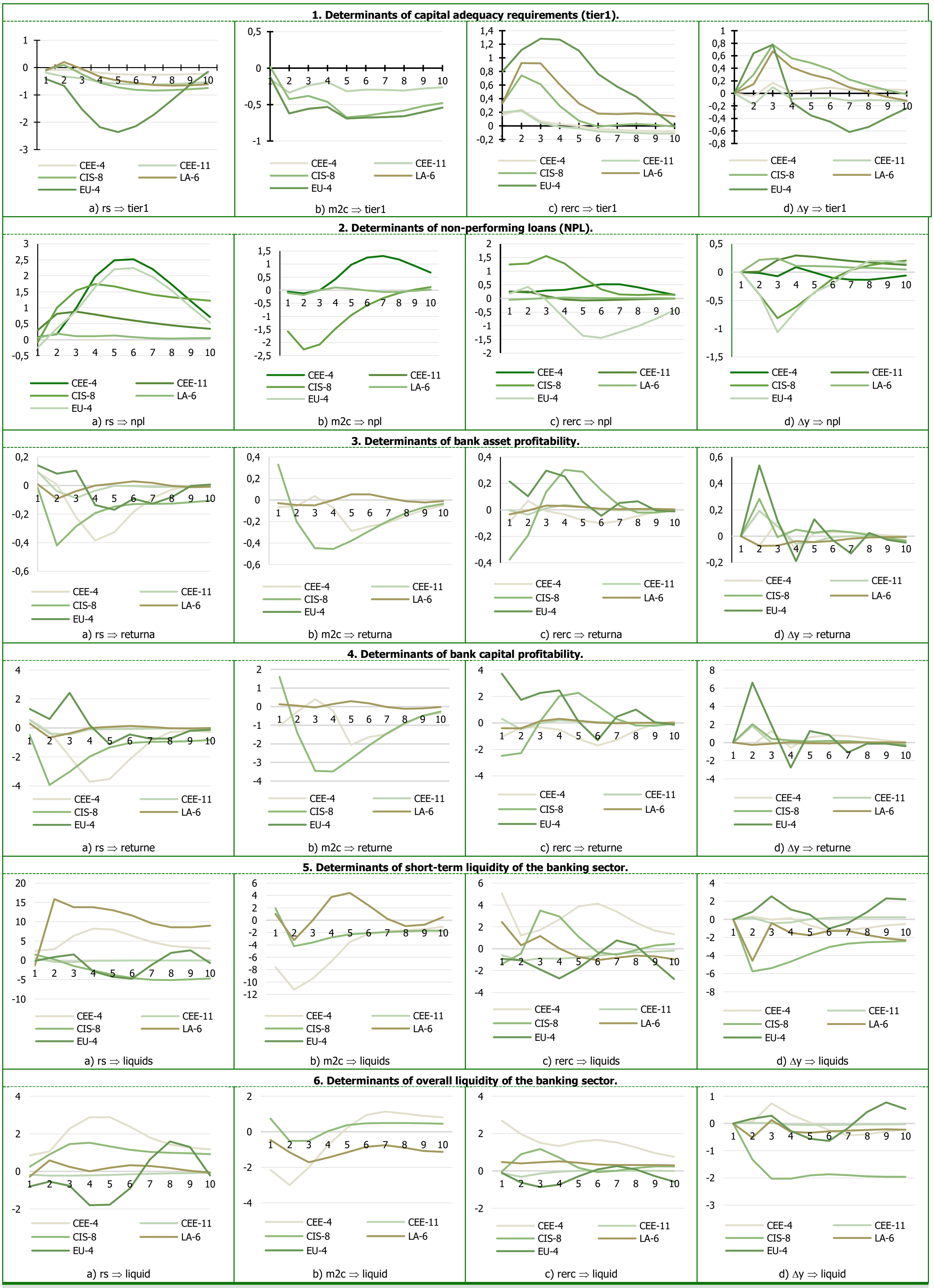

Figure 1. Determinants of selected financial stability indicators.

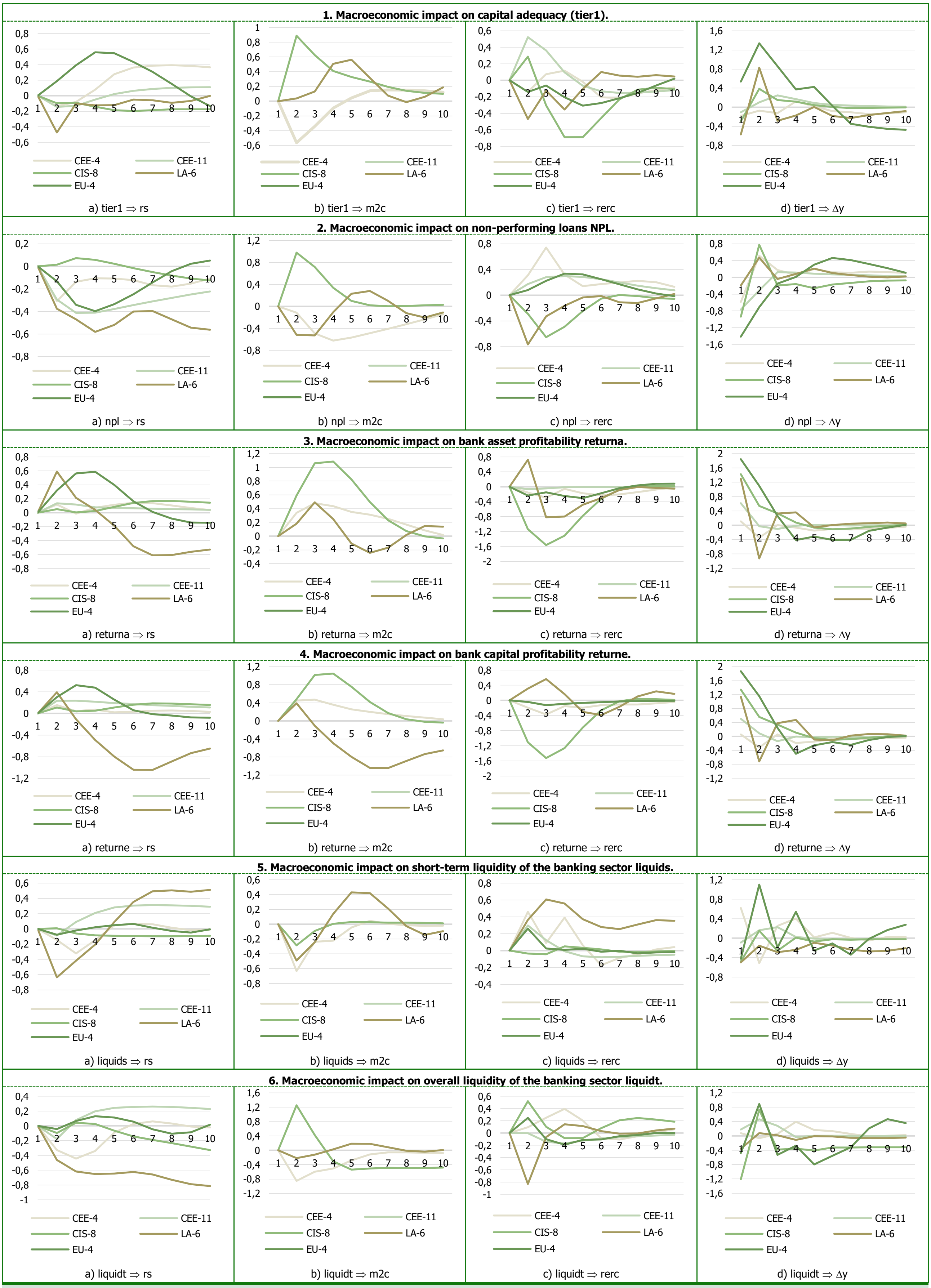

Figure 2. Macroeconomy impact on selected financial stability indicators.

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Evidence from 15 industrialized countries spanning over 100 years suggests that the prolonged use of expansionary monetary policy significantly increases the probability of financial crises (Boshkoska, 2022). The immediate cause is typically an expansion in credit volumes and overheating in specific markets, such as equity or real estate markets. Moreover, expansionary monetary policy negatively affects GDP dynamics in the medium term, which can be attributed to deteriorating financial stability.

A common feature of most modern financial crises is a significant capital inflow, accompanied by an expansion in the scope of the banking sector's activities (Madeira, 2024). For instance, a study on Bangladesh found that GDP dynamics do not influence the volume of non-performing loans (NPLs); however, such an impact is exerted by interest rates and inflation (Nargis et al., 2019).

An increase in the cost of credit resources, as characterized by the short-term interest rate (*rs*), results in a persistent decline in the capitalization ratio (*tier1*) within the CEE-11 group. In the EU-4 countries, a similar impact is less persistent over time but significantly more substantial, with the weight of *rs* in the variance decomposition of *tier1* residuals rising from 13% to 50%. In contrast, a direct positive relationship between *rs* and *tier1* is observed for the LA-6 countries, where the weight in the variance decomposition remains at 7–8%. Weak evidence of a similar, yet direct and short-lived, dependence is found for the CIS-8 group. No relationship is observed between the interest rate and the capitalization ratio for the CEE-4 group; instead, this group exhibits a heightened negative impact from the monetary overhang, with its weight in the variance decomposition ranging from 8% to 16%.

The undervaluation of the RER (Real Exchange Rate) is a significant factor in increasing the capitalization ratio in LA-6 countries (with a weight of 10–11% in the variance decomposition), as well as in EU-4 countries (8%), where this impact peaks after 4–5 years and subsequently weakens rapidly. Minor evidence of a short-term (up to two years) direct impact is observed in the CEE-4 and CIS-8 groups. GDP dynamics do not influence the capital adequacy ratios of the CEE-4 and CEE-11 countries. This distinguishes them from the LA-6 and EU-4 groups, where a negative impact emerges with a lag of several years (the weight of Δy in the variance decomposition of *tier1* for EU-4 reaches 9%). A specific characteristic of the CIS-8 countries is that GDP growth tends to increase the capitalization ratio (with a weight in the variance decomposition reaching 9%). Except for the EU-4 group, changes in the capitalization ratio exhibit considerable inertia.

Evaluating the feedback effects between the capitalization ratio and macroeconomic indicators, a higher capitalization ratio significantly increases the short-term interest rate in EU-4 countries (the weight of *tier1* in the variance decomposition of *rs* residuals is 16%). Certain evidence of a similar impact is observable in CEE-4 countries (where the weight of *tier1* in the *rs* variance decomposition reaches 11%). There is virtually no resulting increase in the monetary overhang. An impact on the RER is found only for the CEE-11 group, where an increase in reserve requirements is accompanied by a short-term decline in this indicator (the weight of *tier1* in the variance decomposition of *rerc* reaches 8%). In most countries, there is no evidence of a significant slowdown in GDP dynamics. On the contrary, an acceleration of GDP growth can be expected in EU-4 countries (the weight of *tier1* in the Δy variance decomposition reaches 14%), as well as in the CEE-11 group. However, in the latter case, the variance decomposition suggests that such a causal link is marginal. For LA-6 countries, an immediate consequence of higher reserve requirements may be a short-term decline in the GDP growth rate, but this effect disappears after one year; however, a return of the negative impact can be expected with a 7–8-year horizon (the weight of *tier1* in the Δy variance decomposition is up to 8%).

The results are quite similar in that an increase in the interest rate leads to a rise in non-performing loans (NPLs), though to a lesser extent in the LA-6 and EU-4 countries. In all cases, the weight of *rs* in the variance decomposition of *NPL* residuals is quite high, reaching its peak in the CEE-4 group at over 40%. For these countries, the weight of the monetary overhang is also substantial, exceeding 20%. While NPL volumes increase in the CEE-4 countries, the opposite is observed for the CIS-8 group. The LA-6 countries exhibit a more complex dependence on the monetary overhang: a decrease followed by an increase, which then shifts to a subsequent decline in non-performing loans.

At the same time, higher volumes of non-performing loans possess the potential to induce a prolonged decline in interest rates in the CEE-11 and EU-4 countries, where the weight of *NPL* in the variance decomposition of *rs* residuals reaches 23% and 17%, respectively. In the CEE-4 group, a similar impact lasts no more than a year, and the variance decomposition does not indicate any significant causality. Non-performing loans appear to be a factor contributing to an increase in the monetary overhang in the CIS-8 countries, whereas the opposite can be expected for the CEE-4 group (where the weight of *NPL* in the variance decomposition of *rerc* gradually rises to 9%). In the LA-6 countries, there is no distinct dependence of the monetary overhang on the volume of non-performing loans.

A minor, short-term impact of RER undervaluation is observed in the CEE-11 and CIS-8 countries (in both cases, the weight of *rerc* in the variance decomposition of *NPL* residuals does not exceed 10%). At the same time, in CEE-11 countries, non-performing loans become a significant factor in the decline of the RER, which can be attributed to the consequences of reduced aggregate demand (the weight of *NPL* in the variance decomposition of *rerc* is 6–7%). A similar impact is observed with a lag of 4–5 years in EU-4 countries and with a one-year lag in the CEE-4 group. No dependence of the RER on NPL volumes is found in the CIS-8 and LA-6 countries.

The intuitively expected reduction in non-performing loans resulting from economic growth occurs only in the EU-4 countries. Conversely, in the CEE-11 and LA-6 groups, a higher GDP growth rate materializes as an increase in the volume of non-performing loans (for the LA-6 countries, the weight of Δy in the variance decomposition of *NPL* exceeds 20%). Following the initial increase in NPL volumes, the subsequent cleaning of the banking system is characterized by considerable inertia across all countries.

Except for the LA-6 countries, an increase in non-performing loans acts as a restrictive factor in the short term. The corresponding effect is corrected almost immediately in the CEE-4 and CIS-8 groups (where the weight of *NPL* in the variance decomposition of Δy is 10% and 7%, respectively). The process of neutralizing the initial negative impact appears to be more prolonged in the EU-4 countries (with the weight of *NPL* in the Δy variance decomposition reaching 13%).

An increase in the interest rate results in a short-term decline in the return on bank assets across all countries, except for the EU-4 group, where the significance of the interest rate factor in the variance decomposition of *returna* reaches 39%. In the remaining countries, however, this indicator does not exceed 6%, which is relatively low. Similarly, the EU-4 countries exhibit an inverse dependence of the interest rate on the return on bank assets (the weight of *returna* in the variance decomposition of *rs* residuals reaches 17–20%). A similar short-term increase in the interest rate is observed in the CEE-11 group, though this impact does not appear to be significant. In both cases, the rising cost of credit resources can be attributed to attempts to neutralize credit booms, which are typically characterized by increasing return on bank assets.

The monetary overhang leads to a lagged decline in the return on bank assets in the CEE-4 countries, where this factor accounts for 17–23% of the variance decomposition. A similar reduction in *returna* can be expected for the CIS-8 group, albeit with the possibility of an immediate stimulative effect in the current period (the weight in the variance decomposition is 13%). For the LA-6 countries, the impulse response function indicates the potential for an increase in the return on bank assets with a significant time lag; however, this dependence is not significant. Weak evidence of an increase in the monetary overhang following a rise in the return on bank assets is observed in the CEE-4 and CIS-8 groups, but this causality lacks statistical significance.

For the CIS-8 group, an undervaluation of the RER initially reduces the return on assets in the current period; however, a favorable dependence emerges over time (the weight of *rerc* in the variance decomposition of *returna* is 6%). An undervalued RER is similarly beneficial for the return on assets in the EU-4 countries (with a weight of 9% in the variance decomposition). Only in the CIS-8 group is the dependence of the RER on the return on bank assets observed at a statistically significant level, although the weight of *returna* in the variance decomposition of *rerc* does not exceed 10%. Certain evidence of a resulting increase in the RER is noticeable in the EU-4 countries, which may be a consequence of rising consumer prices driven by the increased lending activity of banking institutions.

Economic growth is conducive to a short-term increase in the return on bank assets in the CEE-11, CIS-8, and EU-4 countries (with the Δy factor being most significant in the latter group). Only for the LA-6 countries is the GDP dynamics unfavorable for the return on assets within the banking system. In most of the studied countries, a higher return on bank assets creates a short-term expansionary impulse, which is more persistent in the EU-4 group (where the weight of *returna* in the variance decomposition of Δy reaches 25%). In contrast, in the LA-6 countries, it shifts toward a decline in the GDP growth rate (with the weight of *returna* in the Δy variance decomposition at 18%). The estimates for the return on bank equity (ROE) differ only slightly from those for the return on bank assets (ROA), with a few exceptions:

1. The inverse dependence on the interest rate becomes more pronounced in the CIS-8 countries.
2. Inverse dependence on the RER (*rerc*) emerges with a six-year lag, alongside a direct dependence on the dynamics of economic growth (Δy) in the CEE-4 countries.
3. Additionally, the weight of monetary overhang in the variance decomposition of *returne* residuals is reduced by nearly half.

A higher return on equity (ROE) does not affect the short-term interest rate in the CEE-4, CIS-8, and LA-6 countries, which is largely consistent with the observed dependencies for return on assets (ROA). However, such an impact is present in the EU-4 and CEE-11 groups — in the former, the contribution of ROE to the variance decomposition of *rs* residuals reaches 15%, while in the latter, it amounts to 6%. For the CEE-4 and CIS-8 countries, the profitability of either bank equity or assets appears to trigger the emergence of a monetary overhang; however, the statistical significance of this link remains relatively low, and the variance decomposition does not confirm the substantiality of such a causal relationship.

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A higher return on assets (ROA) is expected to lead to an increase in the RER in the CIS-8 (where the weight of *returna* in the variance decomposition of *rerc* is 8%) and EU-4 (6%) countries. A similar relationship is observed for the return on equity (ROE). Certain differences were identified for the LA-6 group, where the PVAR model including bank equity, shows an increase in the RER with a 3–4-year lag (the weight of r*eturna* in the variance decomposition of *rerc* reaches 10%). No differences were found regarding the impact of bank assets and equity profitability on GDP dynamics. A short-term expansionary effect is observed for the CEE-11, CIS-8, and EU-4 countries. For the LA-6 group, the initial expansionary impulse is neutralized after one year, while for the CEE-4 countries, no impact of bank profitability on GDP dynamics is detected.

In the event of an interest rate increase, the short-term liquidity of the banking system declines temporarily in the CEE-4 countries (where the weight of *rs* in the variance decomposition of liquids residuals is 10%), whereas a corresponding effect in the CIS-8 group emerges with a significant time lag (with the weight of *rs* in the liquids variance decomposition at 6%). Conversely, the LA-6 countries experience a substantial improvement in short-term liquidity (the weight of *rs* in the variance decomposition of *liquids* exceeds 40%). While the corresponding impulse response function for the CEE-4 countries lacks statistical significance, the variance decomposition indicates the relevance of the dependence of short-term liquidity on the interest rate. For these countries, an inverse relationship between the monetary overhang and short-term liquidity is also significant (the weight of m2c in the variance decomposition of *liquids* exceeds 20%).

The feedback loop between short-term banking liquidity and the interest rate is very pronounced in the CEE-11 countries (where the weight of *liquids* in the variance decomposition of *rs* gradually increases to 14%). Weak signs of a short-term inverse relationship between liquids and *rs* are noticeable in the CEE-4 group, while no impact is observed in the remaining countries studied. The monetary overhang impairs liquidity in the CEE-4 and LA-6 countries; however, in Latin American countries, a rise in short-term banking liquidity occurs with a 5–6-year lag.

Except for the CEE-11 countries, there is no evidence of a dependence of short-term banking liquidity on the RER. At the same time, an improvement in liquidity can be expected to induce a short-term undervaluation of the RER in the CEE-4 and CEE-11 groups; however, in both cases, the weight of *liquids* in the variance decomposition of *rerc* residuals is insignificant.

GDP growth results in a prolonged decline in short-term bank liquidity in the CIS-8 countries, whereas a similar impact is short-lived in the LA-6 group. Conversely, the EU-4 countries experience a slight improvement in short-term liquidity with a two-year lag. In all cases, the weights of *rerc* and (Δy in the variance decomposition of *liquids* residuals are insignificant. An inverse dependence of GDP dynamics on short-term banking liquidity is observed only in the CEE-4 countries (where the weight of *liquids* in the variance decomposition of Δy residuals is 10%).

An increase in the short-term interest rate enhances the overall liquidity of the banking system in the CEE-4 countries (where the weight of *rs* in the variance decomposition of *liquidt* residuals gradually rises to 20%) and the CIS-8 group (5–6%). The feedback effect of liquidity on the interest rate is similar to that of short-term liquidity. A prolonged inverse relationship between liquidity and the interest rate is observed primarily in the LA-6 countries, although its statistical significance remains low.

The monetary overhang exerts a short-lived negative impact on the liquidity of the banking system in the CEE-4 countries (where the weight of *m2c* in the variance decomposition of *liquidt* residuals is 18%), whereas a similar dependence proved to be persistent over time for the LA-6 group (with the weight of *m2c* reaching 20%). No such effect is observed for the CIS-8 countries. Conversely, the overall liquidity of the banking system leads to a reduction in the monetary overhang in the CEE-4 group, while the exact opposite is observed in the CIS-8 countries (in both cases, the weight of *liquidt* in the variance decomposition of *m2c* residuals does not exceed 10%).

A decline in the RER improves the overall liquidity of the banking system in the CEE-4 countries (where the weight of *rerc* in the variance decomposition of *liquidt* residuals is 15%) and, to a lesser extent, in the CIS-8 group; however, this impact is short-lived. No statistically significant feedback effect of banking system liquidity on the RER is observed in any of the countries studied.

A persistent inverse relationship between GDP dynamics and the overall liquidity of the banking system is observed only in the CIS-8 countries (where the weight of Δy in the variance decomposition of *liquidt* residuals exceeds 10%). The feedback effect of liquidity on GDP dynamics is favorable for the CEE-11 (with the corresponding impulse lasting three years) and CEE-4 (with a four-year lag) groups. For the CIS-8 countries, an initial slowdown in GDP dynamics is followed by a contrasting expansionary effect; however, the GDP growth rate subsequently deteriorates again (the impact is quite significant, as the weight of *liquidt* in the variance decomposition of Δy exceeds 10%.

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For convenience, the results obtained are summarized in Table 1. The relationship between capitalization requirements (*tier1*) and the short-term interest rate (*rs*) appears to be weak. Apart from the EU-4 and, to a lesser extent, CEE-4 countries, higher capitalization requirements do not result in an increase in the interest rate. It should be noted that an inverse relationship between *rs* and *tier1* may reflect concerns regarding the consequences of implementing stricter capitalization mandates. There is no evidence that higher capitalization requirements lead to a slowdown in GDP dynamics; on the contrary, an expansionary effect is observed in the CEE-11, LA-6, and EU-4 countries. At the same time, the reverse causality ($\Delta y \Rightarrow tier1$) is quite diverse across different groups of countries. The link between capitalization requirements and the RER is weak in all groups, and the mutual dependence between capitalization requirements and the monetary overhang is heterogeneous.

As expected, an increase in non-performing loans (NPLs) is predominantly unfavorable for GDP dynamics, which may explain the accompanying decline in the interest rate, especially when the higher cost of credit resources contributes to the growth of NPL volumes. The elevated risks for the LA-6 and CEE-11 countries are evidenced by the fact that economic growth does not reduce NPL volume unlike in the EU-4 group, where this causal relationship is quite pronounced. An increase in NPLs generally reduces the RER (except for the LA-6 countries), which may have an unfavorable feedback effect (as seen in the CEE-11 group). If a monetary overhang leads to an increase (or decrease) in non-performing loans, it triggers an asymmetric inverse impact on NPL volumes.

Table 1. Generalized characteristics of the interrelationship between financial stability parameters and selected macroeconomic indicators. Note: ↑ (↓) indicates a positive (negative) impact of the endogenous variable in the impulse response function, while "N" denotes the absence of a functional relationship.

Group of countries					Group of countries				
CEE-4	CEE-11	CIS-8	LA-6	EU-4	CEE-4	CEE-11	CIS-8	LA-6	EU-4
rs ⇒ tier1					tier1 ⇒ rs				
N	↓	N	↑	↓-N	N-↑-N	N	N	N	↑-N
m2s ⇒ tier1					tier1 ⇒ m2c				
↓		N	↓-N		↓-N		↑-N	N-↑-N	
rerc ⇒ tier1					tier1 ⇒ rerc				
↑-N	N	N	↑	N-↑-N	N	↑-N	N	N	N
∆y ⇒ tier1					tier1 ⇒ ∆y				
N	N-↓	↑	↓	↑-↓-N	N	N-↑-N	N	N-↑-N	↑-N
rs ⇒ npl					npl ⇒ rs				
N-↑-N	↑	↑	↑-N	N	↓-N	↓	N	N	↓-N
m2s ⇒ npl									
N-↑		↓-N	↓-↑		N-↓		↑-N	↓-N	
rerc ⇒ npl					npl ⇒ rerc				
N	↑-N	↑-N	N	N	N-↑-N	↑	N	↓-N	N-↑-N
∆y ⇒ npl					npl ⇒ ∆y				
N	N-↑	N	↑	↓-N	↓-↑-N	↓-N	↓-↑-N	N	↓-N
rs ⇒ returna					returna ⇒ rs				
N-↓-N	N-↓-N	↓-N	N	N	N	↑	N	N	↑-N
m2s ⇒ returna					returna ⇒ m2c				
N-↓-N		N-↓	N-↑-N		↑		↑	N	
rerc ⇒ returna					returna ⇒ rerc				
N	N	↓-↑-N	N	N-↑-N	N	N	↓-N	N	N
∆y ⇒ returna					returna ⇒ ∆y				
↑-↓	↑-↓-N	↑-N	↓	↑-N	N	↑-N	↑-N	↑-↓-N	↑-N
rs ⇒ returne					returne ⇒ rs				
N-↓-N	N	↓-N	N	N	N	↑	N	N	↑-N
m2s ⇒ returne					returne ⇒ m2c				
N-↓-N		N-↓-N	N		↑-N		↑-N	N	
rerc ⇒ returne					returne ⇒ rerc				
N-↓-N	N	↓-↑-N	N	↑-N	N	N	↓-N	N-↓-N	N-↓-N
∆y ⇒ returna					returne ⇒∆y				
N-↑	↑-N	N	N	↑-↓-N	N	↑-N	↑-N	↑-↓-N	↑-N
rs ⇒ liquids					liquids ⇒ rs				
↑	↓-↑	↓	↑	N	↓-N	N-↑	N	N	N
m2s ⇒ liquids					liquids ⇒ m2c				
↓		N	N		↓-N		N	↓-↑-N	

(continued on next page)

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Table 1. Continued.

Group of countries					Group of countries				
CEE-4	CEE-11	CIS-8	LA-6	EU-4	CEE-4	CEE-11	CIS-8	LA-6	EU-4
rerc ⇒ liquids					liquids ⇒ rerc				
N	↓	N	N	N	↑-N	↑-N	N	N	N
Δy ⇒ liquids					liquids ⇒ Δy				
N	N	↓	↓-N	↑-N	↑-↓-N	N	N	N-↓	N
rs ⇒ liquidt					liquidt ⇒ rs				
↑	N	↑	N	N	↓-N	↓-↑	N	↓	N
m2s ⇒ liquidt					liquidt ⇒ liquidt				
↓-N		N	↓		↓-N		↑-N	N	
rerc ⇒ liquidt					liquidt ⇒ rerc				
↑	N	N	N	N	N	N	N	↓-N	↓-N
Δy ⇒ liquids					liquidt ⇒ Δy				
N	N	↓	N	N	N-↑-N	↑-N	↓-↑-↓	N	N

As expected, higher profitability of bank assets and equity is predominantly favorable for economic growth. In turn, GDP dynamics in most cases increase the return on bank equity; however, this outcome is less convincing regarding the return on bank assets. Higher profitability of both banking system indicators is accompanied by an increase in the interest rate only in the CEE-11 and EU-4 countries, which can be explained by the specifics of Eurozone membership or the pegging of the national currency to the euro. If higher profitability of the banking system reflects the realities of an economic boom and an increase in aggregate demand, the threat of economic 'overheating' prompts an interest rate hike by the European Central Bank — and, accordingly, by the countries that maintain a peg to the single European currency, the euro — for stabilization purposes. It can be assumed that countries with a floating exchange rate attempt to avoid interest rate increases due to concerns regarding excessive currency appreciation.

The monetary overhang is predominantly unfavorable for the return on bank assets and equity, whereas the reverse dependence, specifically the impact of both profitability indicators on the monetary overhang, is characterized by a prevailing favorable effect. Mutual dependence between the RER and both financial stability parameters is absent in the CEE-11, LA-6, and CEE-4 countries, while in the other two groups, the direction of causality almost coincides (except for *returne* ⇒ *rerc*).

It appears that both short- and long-term banking system liquidity have virtually no impact on the macroeconomic indicators of the EU-4 countries (except for RER appreciation resulting from *liquidt*). Likewise, in these countries, there is no dependence of the banking system liquidity on the studied macroeconomic indicators (with the exception of a favorable dependence of *liquids* on Δy). In the remaining countries, the functional dependencies are quite diverse.

Overall, the obtained results demonstrate the absence of universal dependencies between individual financial stability parameters and macroeconomic indicators. Just as history has never seen two identical crises, it can be argued that no similar functional dependencies exist for all countries without exception. This implies that when determining priorities for enhancing the anti-crisis resilience of individual countries, it is essential to consider the specifics of their structural characteristics.

Regardless of the VAR model specification, an increase in the interest rate has the expected immediate restrictive impact on income dynamics in the CEE-4, CEE-11, and LA-6 countries. A distinctive feature of the CIS-8 group is that an opposite effect subsequently follows this short-term restrictive impact. In contrast to the other studied regions, for the EU-4 countries, the nature of the relationship between *rs* and Δy depends on the VAR model specification. When accounting for *tier1, npl, returna*, and *returne*, the immediate consequence of a short-term interest rate hike is an increase in the GDP growth rate, which later shifts to the usual restrictive effect. However, in the VAR model including the *liquids* and *liquidt* variables, the initial expansionary effect is absent, and the functional dependence for income becomes similar to that of the other studied countries.

As the variance decomposition shows, the weight of the interest rate in GDP fluctuations is relatively insignificant in the CEE-11 and CIS-8 countries, where this indicator does not exceed 6–7%. For the CEE-4 and LA-6 groups, the weight of *rs* in the variance decomposition of Δy residuals reach 16% and 14%, respectively. The dependence of GDP dynamics on the interest rate is much higher in the EU-4 countries. In the VAR model including the *tier1* indicator, the weight of *rs* in the variance decomposition of Δy residuals gradually increase from 8% to 23%, while in VAR models with *npl, returna*, and *returne*, it is slightly lower, not exceeding 16%. A completely different level of significance regarding the dependence of

GDP dynamics on the interest rate is demonstrated by VAR models including banking system liquidity indicators, where the factor's weight in the variance decomposition gradually rises from 64% to 72% and even 80%.

The monetary overhang initially accelerates GDP dynamics, but the GDP growth rate subsequently undergoes a correction. Certain signs of a recovering expansionary effect are observed only in the LA-6 countries. The weight of the monetary factor in the variance decomposition of Δy residuals is quite high in the CEE-4 group, where, depending on the VAR model, this indicator gradually increases to 18–28%. In the LA-6 countries, the monetary overhang accounts for 13–15% of the changes in GDP dynamics, while for the CIS-8 group, the impact is relatively insignificant, at no more than 5%.

A short-term expansionary effect of a depreciated RER is observed in the CEE-4 and CEE-11 countries. In the CIS-8 group, a similar stimulative effect is more persistent over time. In the LA-6 countries, a depreciated RER has a short-term restrictive impact, which contrasts with the countries of Eastern Europe and the former Soviet Union. For the EU-4 group, the expansionary effect occurs only in the current period. As revealed by the variance decomposition of income residuals, the weight of the price factor is insignificant in the CEE-4, CEE-11, and CIS-8 countries. However, in the LA-6 group, the weight of *rerc* in the Δy decomposition gradually decreases from 19–21% to 8–15%, which is quite substantial. Similarly, the dependence of GDP dynamics in the EU-4 countries on the RER can be considered significant, as the weight of *rerc* in the Δy decomposition gradually declines from 15–22% to 5–16%, depending on the VAR model specification.

DISCUSSION

Among the identified functional relationships, an increase in the interest rate produces the expected immediate restrictive effect on income dynamics in most countries; however, in the CIS-8 group, this effect is subsequently reversed. In all countries studied, the monetary overhang initially accelerates GDP growth, followed by a correction phase. A short-term expansionary effect of a depreciated RER is observed in most countries, whereas in the LA-6 group, the effect is the opposite.

Unlike existing studies, which examine financial stability through the lens of individual factors—such as financial inclusion (Ahamed & Mallick, 2019; Hakimi et al., 2022), geopolitical risks (Trinh & Tran, 2024) or fintech penetration (Pham, 2026)—the approach we propose involves a comprehensive comparative analysis of the interdependence between financial stability indicators and key macroeconomic indicators across five representative groups of countries, distinguished by their exchange rate regimes and financial crisis histories. At the same time, it should be noted that the results and conclusions obtained have certain limitations that should be taken into account when interpreting them: the analysis covers a limited set of countries and does not claim to be fully representative of all economies worldwide.

CONCLUSIONS

Based on the empirical analysis conducted using VAR models on data from Eastern European countries with floating and fixed exchange rates (CEE-4 and CEE-11, respectively), the former Soviet Union (CIS-8), as well as Latin America (LA-6) and Southern Europe (EU-4), the following dependencies for financial stability indicators have been identified:

1. Except for the EU-4 and, to a lesser extent, CEE-4 countries, higher capitalization requirements do not result in an increase in the interest rate and do not have a negative impact on GDP dynamics; moreover, an expansionary effect is observed in the CEE-11, LA-6, and EU-4 groups. In the event of an interest rate hike, the capitalization ratio decreases in the CEE-11 and EU-4 countries, while in the LA-6 and CIS-8 groups (to a lesser extent), it increases. The dependence of capitalization requirements on GDP dynamics varies significantly across individual countries, whereas the link between capitalization requirements and the RER is weak in all groups. The mutual dependence between capitalization requirements and the monetary overhang is heterogeneous.
2. An increase in non-performing loans is predominantly unfavorable for GDP dynamics, which may explain the accompanying decline in the interest rate; it is also accompanied by a decrease in the RER (except the LA-6 countries), which may also have an unfavorable feedback effect (as seen in the CEE-11 group). If a monetary overhang leads to an increase (or decrease) in non-performing loans, it triggers an asymmetric inverse impact on the volume of non-performing loans.
3. Higher profitability of bank assets and equity is predominantly favorable for economic growth and may be accompanied by an increase in the interest rate for countries with a fixed exchange rate (CEE-11 and EU-4). In most cases, GDP dynamics increase the return on bank equity. The monetary overhang is predominantly unfavorable for the return on bank assets and equity, whereas the reverse dependence of the monetary overhang on both indicators

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is characterized by a prevailing favorable impact. Mutual dependence between the RER and both financial stability parameters is absent in the CEE-11, LA-6, and CEE-4 countries, while in the other two groups, the direction of causality almost coincides.

4. Short- and long-term banking system liquidity has virtually no impact on the macroeconomic indicators of Southern European countries, whereas in the remaining countries, the functional dependencies are quite diverse.

Future research will focus on analyzing how the digital transformation of the financial sector, particularly the rapid growth of neobanking and fintech, is affecting traditional indicators of financial stability.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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МОДЕЛЮВАННЯ РІВНЯ ФІНАНСОВОЇ СТАБІЛЬНОСТІ КРАЇНИ: ЕКОНОМІКО-МАТЕМАТИЧНИЙ ПІДХІД

Глобальний характер останніх у часі фінансових криз чітко показує, що інтеграція фінансових ринків пропонує багато переваг, але може створювати значні ризики з великими втратами в реальному секторі. Аналіз трансформації фінансових ринків важливий для виявлення загроз у глобальному конкурентному просторі, що залишається турбулентним і вразливим до кризових явищ, а також для формування такого захисту від несприятливого перебігу подій, який не перешкоджає динаміці економічного зростання.

Особливої актуальності ця проблематика набуває в умовах становлення цифрової економіки та суспільства, де впровадження інноваційних моделей життєзабезпечення породжує нові канали поширення системних ризиків і підвищує структурну неоднорідність національних фінансових систем, що вимагає відповідного вдосконалення економіко-математичного інструментарію їх моделювання.

Ми розробили методологію порівняльного аналізу параметрів фінансової стабільності за допомогою VAR-моделей, що дозволило виявити відсутність універсальних залежностей у розрізі окремих країн між параметрами безпечності банківської системи та основними макроекономічними показниками (динаміка ВВП, процентна ставка, реальний обмінний курс, грошова емісія); за даними країн Східної Європи й колишнього Радянського Союзу, а також Латинської Америки й Південної Європи, отримано, що: а) вищі вимоги капіталізації переважно не позначаються підвищенням процентної ставки й не мають негативного впливу на динаміку ВВП, б) якщо зростання проблемних позик переважно несприятливе для динаміки ВВП, то протилежний вплив має вища рентабельність банківських активів і капіталу, в) коротко- й довгострокова ліквідність банківської системи практично не впливає на макроекономічні показники країн Південної Європи, а в решті країн функціональні залежності досить різноманітні.

Загалом отримані результати показують відсутність універсальних залежностей між окремими параметрами фінансової стабільності та макроекономічними показниками. Це означає, що визначення пріоритетів для підвищення антикризової стійкості окремих країн повинно враховувати специфіку їхніх структурних характеристик.

Ключові слова: банки, кризи, ризики, фінансова стабільність, інвестиції, ВВП, реальний обмінний курс, економічне зростання, модель панельної авторегресії

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