Uzbekistan's Financial Stress Index

Abstract

This methodological framework examines various approaches to constructing the Financial Stress Index (FSI) based on international experience. It also discusses the applicability of different methods for constructing the index in light of their respective characteristics and presents the methodology for calculating the FSI for Uzbekistan. The calculation process involves selecting effective indicators that capture changes in financial conditions, standardizing the indicators, aggregating them into sub-indices, and combining the sub-indices into a composite index. The objective of this article is to develop the necessary tools for assessing the magnitude of risks in Uzbekistan's financial system.

Keywords: financial stress index, financial system, indicator, subindex, standardization.

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To calculate the FSI, first, effective indicators that represent changes in the financial system are selected. These indicators are then standardized and combined into subindices that show the condition of the financial sectors. Based on their significance, the weights of the subindices are determined. Finally, the values and weights of the subindices are used to calculate the FSI.

Selection of effective indicators. Selecting effective indicators when calculating the FSI is crucial to ensure the reliability of the index results. Indicators can be chosen based on the country's characteristics and experiences of other countries or evaluated using econometric models to determine their significance level.

When selecting indicators, choosing those readily available with a high-frequency publication, representing market-wide developments, and having sufficient time series is essential[1]. The Area under the Receiver Operating Characteristic Curve, AUROC, (United Kingdom[2], Ukraine[3]) and logistic regression (Ukraine) models are commonly used to identify important indicators for FSI calculation.

When evaluating indicators' effectiveness using the AUROC model, Type I[4] and Type II[5] errors are considered to determine how accurately they represent crisis periods[6]. High AUROC values indicate that indicators accurately represent crisis periods, with a value of 0.7 indicating a 70 percent chance that the model correctly distinguishes between crisis and non-crisis events.

Logistic regression models determine the probability of a particular event by identifying significant indicators that accurately represent the crisis period[7].

Standardization of indicators. To compare and combine indicators into subindices, they are first standardized using various methods. Standardization of indicators is done by Z-score (Turkey[8], Ukraine, Albania[9]), logit transformation (Albania), min-

[1] Hollo, D., Kremer, M., & Lo Duca, M. (2012). CISS - A composite indicator of systemic stress in the financial system. European Central Bank.

[2] Chatterjee, S., Chiu, C-W. J., Duprey, T., & Hoke, S. H. (2017). A financial stress index for the United Kingdom. Bank of England.

[3] Filatov, V. (2021). A New Financial Stress Index for Ukraine. National Bank of Ukraine.

[4] In a Type I error, financial stress is not expected to occur, but it does.

[5] In a Type II error, financial stress is expected to occur, but it does not.

[6] Chatterjee, S., Chiu, C-W. J., Duprey, T., & Hoke, S. H. (2017). A financial stress index for the United Kingdom. Bank of England.

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[8] Chadwick, M., & Ozturk, H. (2018). Measuring Financial Systemic Stress for Turkey: A Search for the Best Composite Indicator. Central Bank of the Republic of Turkey.

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max (Macedonia[10], Ukraine), and cumulative distribution function (United Kingdom, Turkey, India[11]) methods.

The Z-score method is based on how much the difference between the indicator's current value and its arithmetic mean is above or below its standard deviation. Indicator standardization through the min-max method is carried out by determining the ratio of the difference between the actual value and the lowest value of the indicator during the observation period to the difference between the highest and lowest values of the same indicator during that same period. The cumulative distribution function method involves placing the values of each indicator in ascending order and assigning them ordinal numbers based on their location. The indicators are then standardized by dividing the given order number by the total number of indicator time series[12].

Aggregation of indicators into a subindex. Standardized indicators are combined into subindices based on their representation of different sectors within the financial system. To calculate the subindex value, either the PCA (Albania) or equal variance (Czech Republic[13]) models are used.

In the equal variance model, the indicators are aggregated into subindices by calculating their arithmetic mean with equal weights. This common method reduces the probability of any single indicator dominating the subindex.

For PCA, a linear transformation is used to reduce the dimension of multiple indicators with mutual correlation while retaining the maximum variance[14]. This process combines several indicators into a single indicator.

Estimating the weights of subindices. To calculate the final FSI, subindices representing various segments of the financial system are first weighted. The weight of subindices can be calculated using models such as AUROC (United Kingdom, Ukraine) and logistic regression (Ukraine[15]). Subindices with high values in these models are assigned higher weights in the final FSI. Additionally, the weights of subindices in the final index can be determined by evaluating their relative impact on

[10] Petroska, M., & Mihajlovska, E.M. (2013). Measures of Financial Stability in Macedonia. Journal of Central Banking Theory and Practice.

[11] Senapati, M., & Kavediya, R. (2020). Measuring Financial Stress in India. Reserve Bank of India.

[12] Hollo, D., Kremer, M., & Lo Duca, M. (2012). CISS – A composite indicator of systemic stress in the financial system. European Central Bank.

[13] Malega, J., & Horvath, R. (2017). Financial Stress in the Czech Republic: Measurement and Effects on the Real Economy.

[14] James, G., Witten, D., Hastie, T., & Tibshirani, R. (2013). An Introduction to Statistical Learning: With Applications in R.

[15] Filatov, V. (2021). A New Financial Stress Index for Ukraine. National Bank of Ukraine.

economic growth and considering factors such as the number of indicators in the subindex or assigning equal weights.

Aggregation of subindices into a final index. In the last stage of calculating the FSI, subindices are aggregated into the final index. The aggregation of subindices into the final index is carried out through the PCA (Belarus[16], India[17]) and portfolio theory (Albania, United Kingdom, Ukraine) models, as well as by calculating the sum or weighted average value of subindices (Czech Republic, Turkey).

The portfolio theory model expresses the FSI as a vector multiplication of the subindices' values, weights, and dynamic correlation matrix. The correlation matrix's elements represent the time-varying cross-correlations among indicators, which are determined using the exponentially weighted moving average (EWMA) and dynamic conditional correlation multivariate generalized auto-regressive conditional heteroskedasticity (DCC-MGARCH) models.

[16] Mazol, A. (2017). The influence of financial stress on economic activity and monetary policy in Belarus. Belarusian Economic Research and Outreach Center.

[17] Senapati, M., & Kavediya, R. (2020). Measuring Financial Stress in India. Reserve Bank of India.

Table 1. Models for FSI Calculation: Applicability in Uzbekistan

Step for FSI calculation	Model	Is sufficient time series data available?	Is crisis dummy needed
Indicators selection	AUROC	Yes	No
	Logistic regression	Yes	No
Indicators standardization	Z-score	Yes	Yes
	Logit transformation	Yes	Yes
	Min-max	Yes	Yes
	Cumulative distribution function	Yes	Yes
Indicators aggregation to subindex	Principal component analysis	Yes	Yes
	Equal variance	Yes	Yes
Subindices' weights estimation	AUROC	Yes	No
	Logistic regression	Yes	No
	Evaluating relative impact on the economic growth	Yes	Yes
Subindices aggregation to final index	Principal component analysis	Yes	Yes
	Portfolio theory	No	Yes

Methodology of Financial Stress Index for Uzbekistan

The banking sector developments are captured using the differences between actual and potential values of deposits and loans using the Hodrick-Prescott (HP) filter and the ratio of net interest income to bank interest-bearing assets were considered. In analyzing the money market, the spread between money market rates and Uzbekistan treasury bill rates, as well as the volatility indicator for the weighted average interest rate of the interbank money market determined by the generalized autoregressive conditional heteroskedasticity (GARCH) model were used. To determine risks in the foreign exchange market, the realized volatility[18] of the exchange rates of the US dollar and euro against the soum was used.

All indicators were standardized using the Z-score method, which is based on the difference between current values and the arithmetic mean of indicators from their standard deviation[19]. Standardized indicators were then aggregated into subindices, which capture changes in the banking sector, money market, and foreign exchange market. The principal component analysis (PCA) model was used for this purpose. Before combining the subindices into the final index, their values were scaled between 0 and 1 using a logarithmic function[20].

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[18] The realized volatility of currency exchange rates is determined by the following formula:

$$rvol_t = \sqrt{\sum_{i=1}^{n} R_t^2}$$

Where:
$rvol$ - realized volatility
R - the difference between the natural logarithm of current and a day prior value of daily currency exchange rates.
t - months
i – days.

[19] Standardization of indicators is carried out by the following formula:

$$y_z = \frac{y_t - y_\mu}{\sigma_{y_t}}$$

Where:
y_z - the standardized value of the indicator
y_t - indicator
y_μ - the arithmetic mean of the indicator
σ_{y_t} - the standard deviation of the indicator
t - months

[20] Subindices are scaled between 0 and 1 by the following logarithmic function:

$$y_{it}{}' = \frac{1}{(1 + \exp(-y_{it}))}$$

The weight of the subindices in the aggregate FSI was determined by evaluating their relative impact on economic growth[21]. Based on the subindex values and determined weights, the final results of the FSI were obtained by computing their weighted average value.

[21] The weight of subindices is determined by the following formula:

$$min \sum_{t=1}^{T} \sum_{i=1}^{4} (GDP\_gr_t - w_i y_i)^2$$
$$\sum_{i=1}^{4} w_i = 1; w_i \geq 0$$

Where:

GDP_gr_t - GDP growth rate

w_i - subindex weight

y_i - subindex

t - quarters

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